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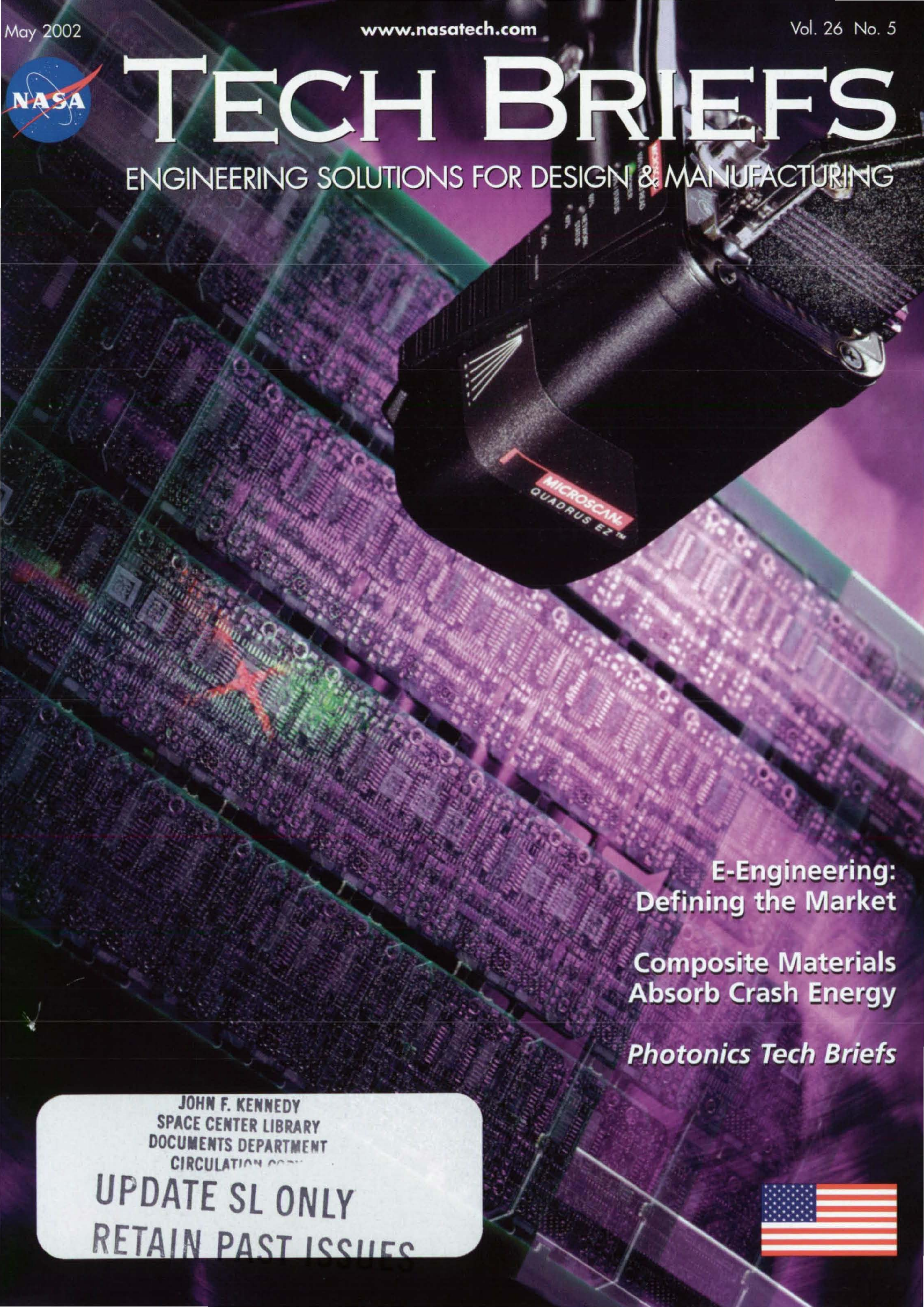
TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING



E-Engineering: Defining the Market

Composite Materials Absorb Crash Energy

Photonics Tech Briefs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Microsoft Project Server 2002

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TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING

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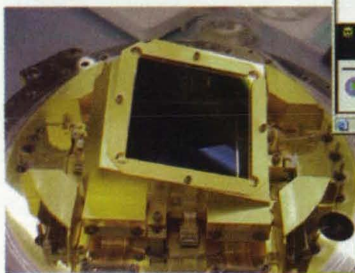

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SOLUTIONS

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SPECIAL SUPPLEMENT

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PRODUCT OF THE MONTH

AccuStudy™ time and motion study software from Advanced Time Studies, Bainbridge Island, WA, lets users gather data for single or multiple time studies, then prepares and displays reports and analyses.

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ON THE COVER

The Quadrus EZ™ bar code scanner from Microscan, Renton, WA, enables manufacturers to use 2D symbols to track components through the manufacturing process. It decodes up to 60 codes per second, and is used in the electronics, automation, document handling, automotive, and packaging industries. For more information on the Quadrus EZ and this month's other new products, see New on the Market on page 81.

(Image courtesy of Microscan)

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (609) 667-7737 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs,* request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Information Technology; Biotechnology; Nanotechnology; Aerospace Operations Systems; Rotorcraft; Thermal Protection Systems.
Carolina Blake
(650) 604-1754
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Jenny Baer-Riedhart
(661) 276-3689
jenny.baer-riedhart@dfrc.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Remote Sensing; Command.
George Alcorn
(301) 286-5810
galcorn@gsfc.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
Merle McKenzie
(818) 354-2577
merle.mckenzie@jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Charlene E. Gilbert
(281) 483-3809
commercialization@jsc.nasa.gov

Kennedy Space Center
Selected technological strengths: Fluids and Fluid Systems; Materials Evaluation; Process Engineering; Command, Control and Monitor Systems; Range Systems; Environmental Engineering and Management.
Jim Aliberti
(321) 867-6224
Jim.Aliberti-1@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Sam Morello
(757) 864-6005
s.a.morello@larc.nasa.gov

John H. Glenn Research Center at Lewis Field
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Larry Viterna
(216) 433-3484
cto@grc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Vernotto McMillan
(256) 544-2615
vernotto.mcmillan@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(228) 688-1929
kirk.sharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

Joseph Allen
National Technology Transfer Center
(800) 678-6882

Ken Dozier
Far-West Technology Transfer Center
University of Southern California
(213) 743-2353

James P. Dunn
Center for Technology Commercialization
Westborough, MA
(508) 870-0042

B. David Bridges
Southeast Technology Transfer Center
Georgia Institute of Technology
(404) 894-6786

Gary Sera
Mid-Continent Technology Transfer Center
Texas A&M University
(409) 845-8762

Charles Blankenship
Technology Commercialization Center
Newport News, VA
(757) 269-0025

Pierrette Woodford
Great Lakes Industrial Technology Transfer Center
Battelle Memorial Institute
(216) 898-6400

NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Carl Ray
Small Business Innovation Research Program (SBIR) & Small Business Technology Transfer Program (STTR)
(202) 358-4652
cray@mail.hq.nasa.gov

Dr. Robert Norwood
Office of Commercial Technology (Code RW)
(202) 358-2320
rnorwood@mail.hq.nasa.gov

John Mankins
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(202) 358-4659
jmankins@mail.hq.nasa.gov

Terry Hertz
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Glen Mucklow
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(202) 358-2235
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Roger Crouch
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(202) 358-0689
rcrouch@hq.nasa.gov

Granville Paules
Office of Mission to Planet Earth (Code Y)
(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
(216) 586-3888

B. Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

Julie Holland
NASA Commercialization Center
Pomona, CA
(909) 869-4477

Bridgette Smalley
UH-NASA Technology Commercialization Incubator
Houston, TX
(713) 743-9155

John Fini
Goddard Space Flight Center Incubator
Baltimore, MD
(410) 327-9150 x1034

Thomas G. Rainey
NASA KSC Business Incubation Center
Titusville, FL
(407) 383-5200

Joanne W. Randolph
BizTech
Huntsville, AL
(256) 704-6000

Joe Becker
Ames Technology Commercialization Center
San Jose, CA
(408) 557-6700

Marty Kaszubowski
Hampton Roads Technology Incubator (Langley Research Center)
Hampton, VA
(757) 865-2140

Paul Myrda
NASA Illinois Commercialization Center
West Chicago, IL
(630) 845-6510

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

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EDS solved.

UpFront

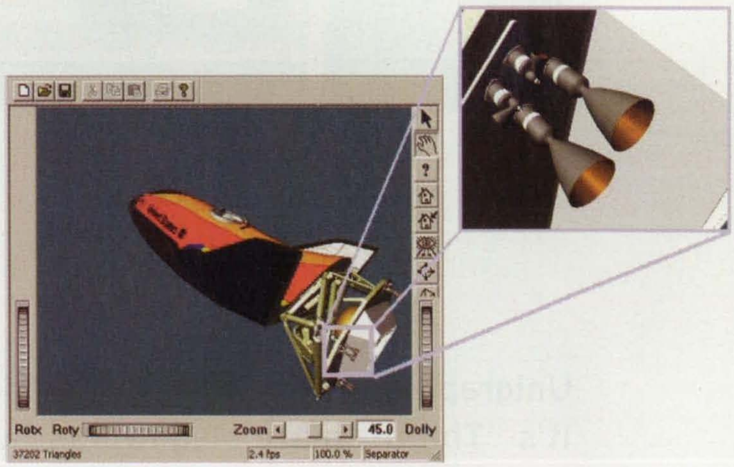
PRODUCT OF THE MONTH

Advanced Time Studies, Bainbridge Island, WA, has introduced AccuStudy™, a computer-based time study method that lets users gather data for single or multiple time studies to improve processes. AccuStudy runs on handheld touchscreen computers running the Microsoft Windows CE® operating system. The software instantly prepares and displays time study results, along with analyses and reports that enable users to pinpoint areas that need attention. The user identifies the icon that represents the process or component being studied, touches it on the screen, and observes it until the next process begins. The software automatically enters appropriate descriptions and value/non-value ratings into the data bank with the observed time. Studies can contain as few as one or as many as 10,000 processes or components. Once data is collected, AccuStudy arranges output into sequential order and lets users create charts, graphs, descriptions, and reports that identify opportunities for greater efficiency.

For Free Info Circle No. 711 or Enter No. 711 at www.nasatech.com/rs

NASA Introduces "Virtual Iron Bird"

A new computer tool under development at NASA's Ames Research Center in California allows engineers to play "what-if" games with computerized spacecraft and other objects. Using personal computers networked to larger machines, researchers can repeatedly play back chunks of time and study them on a computer monitor, examining details such as views of spacecraft from various angles, temperatures, vibrations, sounds, and data from sensors that computers have recorded.



According to project leader Robert Mah of NASA Ames, "If something is broken on a spacecraft, you can troubleshoot the problem 'virtually' using new information technologies to do it quicker and more accurately. You can wander through data-enriched 3D models on the computer screen to see how you can fix the spacecraft."

The new tool is called the "virtual iron bird." Iron bird is an engineering term for a physical model of an aircraft used in part to verify an airplane's systems. The new tool creates a non-physical iron bird model within a computer's memory that engineers can use to analyze past events or test machines before they are built.

The computer interface enables recording of pictures, sounds, and statistics such as temperatures, vibrations, and other measurements that could come from a host of sensors or computer programs. The tool works like a "souped-up" CAD/CAM program that can link to databases of 3D models of machines.

"You can have engineering teams all over the country and the world," said Richard Papasin, a project member at Ames. "Without traveling, team members can use the Internet to see how potential changes could affect the object. A second advantage is that developing a virtual model in computer memory costs much less than a real model."

For more information, visit http://link.abpi.net/l.php?20020305A2 .

Next Month in NTB

The June issue of NTB will include a special feature on the 2001 NASA Commercial and Government Inventions of the Year, awarded each year by NASA's Inventions and Contributions Board. We'll also cover the subject of Electronic Design, including the software and hardware used to design and fabricate electronic devices.

Reader Forum

Reader Forum is dedicated to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a technical problem, or an answer to a previously published question, post your letter to Reader Forum on-line at **www.nasatech.com,** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864. Please include your name, company (if applicable), address, and e-mail address or phone number.

We are involved in the development of an antenna that must be mounted in public roadways, and must sustain motor traffic and weathering. Cars and trucks will be driving over the antenna, and it will be immersed in ice, snow, rain, and slush. The antenna operates in the 800-900 Mhz region and is fed with a foam-filled coaxial cable, probably RG8x. The antenna is a closed cavity design with a ceramic window exposed on the roadway. We would like to have a foam material to fill the antenna cavity in order to preclude the entrance of water and insects. The foam need not have any great physical strength, but it should have a low dielectric constant and loss tangent to minimize de-tuning and loss. The cost of the foaming operation should be minimal and the curing temperatures should be low enough to avoid damage to the feed cable. Thanks for any assistance.

John A. Kuecken
Ke2qj@prodigy.net

Technologies Wanted

Periodically in Reader Forum, we feature abstracts of Demand-Pull Technology Transfer projects. These projects identify technology needs within an industry segment — such as Augmentative Communication — and find solutions to meet those needs. The Rehabilitation Engineering Research Center on Technology Transfer, in partnership with the Rehabilitation Engineering Research Center on Communication Enhancement and the Federal Laboratory Consortium, has developed the Project on Communication Enhancement to identify technologies like those listed below to help persons with communication disabilities who use Augmentative Communication devices. For more details on the project, or to submit technology proposals, visit **http://cosmos.buffalo.edu/aac**.

Input Technologies

Input devices provide control of Augmentative and Alternative Communication (AAC) systems. Input devices should use a wireless link to the AAC system. These include speech recognition technology, gesture recognition, and improved eye gaze technology.

Speech recognition should be accurate and accommodate users with diverse speech characteristics. Gesture recognition must be non-fatiguing and not dependant on user proximity. Improved eye gaze technology should use discrete eye movement to provide accurate control of the AAC system. It should be self-calibrating, non-fatiguing, and unobtrusive.

Dr. Christopher Dellacorte, Oil-Free Turbo Machinery Technical Leader, Glenn Research Center

Dr. Christopher Dellacorte is the Oil-Free Turbo Machinery Technical Leader in the Tribology & Surface Science Branch of NASA's Glenn Research Center in Cleveland, OH. Currently, he is developing new aircraft engines using oil-free turbo engine technology.

***NASA Tech Briefs*: How does oil-free turbine engine technology work and how will it be applied?**

Dr. Christopher Dellacorte: We are taking the oil out of aircraft engines and gas turbines, and replacing the oil-lubricated ball bearings with air-lubricated ball bearings. Oil has temperature limitations because it burns at a few hundred degrees, but air never burns, so we can run red-hot bearings and significantly reduce the weight. We can also improve the ability to run at very high speeds.

NTB: Do you anticipate this becoming mainstream technology?

Dellacorte: That's our intent. What we're doing now is extending the existing technology to bigger, more powerful systems because the bearing technology itself is an industry-owned technology — there are companies that do these kinds of bearings. Bearings are used in small electrical generators and small compressors for aircraft cabin pressurization and air conditioning so that passengers don't have to breathe oil that leaks past seals on an airplane. We've been using bearings for 30 years but the technology and industry have improved to the point where we think we can use them on a small business jet engine, and that's the project that we're currently working on. We expect to run the jet engine in about three years and then we're going to move to bigger jet engines.

NTB: Have you already partnered with industry to develop this technology?

Dellacorte: On our current business jet engine project we're partnering with Mohawk Innovative Technology in Albany, NY, and with Williams International in Walled Lake, MI. We anticipate doing a regional jet class engine or supersonic business jet class engine with many of the U.S. engine companies. The government owns a patent on a coating technology that we develop that makes the bearings work at high temperatures. We have two licensees that do the coating technology: Advanced Materials Products in Twinsburg, OH, and Hohman Plating and Manufacturing in Dayton, OH.

NTB: Do you envision other applications for this technology?

Dellacorte: It could be applicable on microturbines, fuel cell air supply compressors, and turbo chargers. Those are the main applications, in addition to aircraft engines. After 2004, which is when we're going to demonstrate the first small business jet engine, we are going to get started on bigger engines — what we call regional class engines. The regional jet is a new phenomenon that tries to get people to hop airports that are a few hundred or thousand miles apart. We are working to develop a regional jet engine demonstration project and we hope to demonstrate the first engines in 2007.

We're trying to demonstrate to industry that this technology can work; we're not trying to build a commercial product. We're trying to show industry the path so, using their own money, they can then develop commercial versions.

*A full transcript of this interview appears on-line at **www.nasatech.com/whoswho.** Dr. Dellacorte can be reached at Christopher.Dellacorte@grc.nasa.gov*

NASA Patents

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Actuator for Flexing a Resilient Covering

(U.S. Patent No. 6,312,398)

Daniel George Cencer, Johnson Space Center

The power-assisted actuator assembly is designed for flexing restraints in response to movement of an underlying member or controller. The actuator assembly includes a flexible member such as a cord or a fabric panel that has one end coupled to the restraint, and the other end coupled to a drive member such as a drive roller or winch. The drive member, which can be located remotely or locally, pulls on the flexible member to flex the restraint. Coverings and restraints are used to protect underlying members. When that underlying member has a moveable component like a hinged lid or joint, the restraint should move along with the component. For example, body suits and gloves that protect a user from the environment should have restraint layers made to fit closely to the body so that the suit does not prevent or hinder performance of a task. There is a need for an apparatus that reduces the amount of torque required to actuate a restraint layer, such as a glove, that covers a moveable member, such as a hand. This power-assisted joint can include a motion sensor that is coupled to the restraint or is attachable to a human joint and is in electronic communication with the drive member. The assembly is useful in applications including space suit gloves and compliant robot arms.

Conducting Compositions of Matter

(U.S. Patent No. 6,299,800)

Tito Viswanathan, Kennedy Space Center

Electrically conducting polymers are of great interest because of potential applications in which they may replace metals and semimetals that require more energy in processing. One of the problems impeding the development of useful polyconjugated conducting materials is their insolubility in the conducting state. Efforts have been made to create novel, water-soluble, conducting polymers, but the need still exists for electrically conducting polymers that have increased processability and solubility. This invention provides a conductive composition of matter comprising linearly conjugated π-systems and sulfonated polyaryl compounds. It also provides a method comprising producing of a fiber or fabric with improved anti-static properties by contacting the fiber with a conductive composition of matter and one or more formaldehyde-based resins; and by curing the fiber or fabric.

Portable Hyperbaric Chamber

(U.S. Patent No. 6,321,746)

William C. Schneider, James P. Locke, and Horacio M. De La Fuente, Johnson Space Center

This portable, collapsible hyperbaric chamber and airlock system provides the atmospheric pressures required for standard hyperbaric medical treatments, including both hypobaric and hyperbaric decompression sickness associated with aviation, submarine operations, scuba diving, and space activities. The device can be sized to contain at least one patient and one attendant, and can be stored flat with minimal volume. Conventional chambers made of solid metal are heavy and not portable. The new chamber is constructed with a toroidal inflatable skeleton that supports the structure, allowing the attendant and/or patient to enter. Oval hatches mate against bulkhead rings, and the chamber is pressurized. The hyperbaric chamber has an airlock that allows the attendant to enter and exit the patient chamber during treatment. Visual communication is provided through portholes in the patient and/or airlock chamber. Life monitoring and support systems are in communication with the inside of the chamber via conduits and/or sealed feed-through connectors. The chamber can be stowed in the storage area of a room, ship, spacecraft, or other area where space is limited. When deflated, the chamber collapses into a small shape.

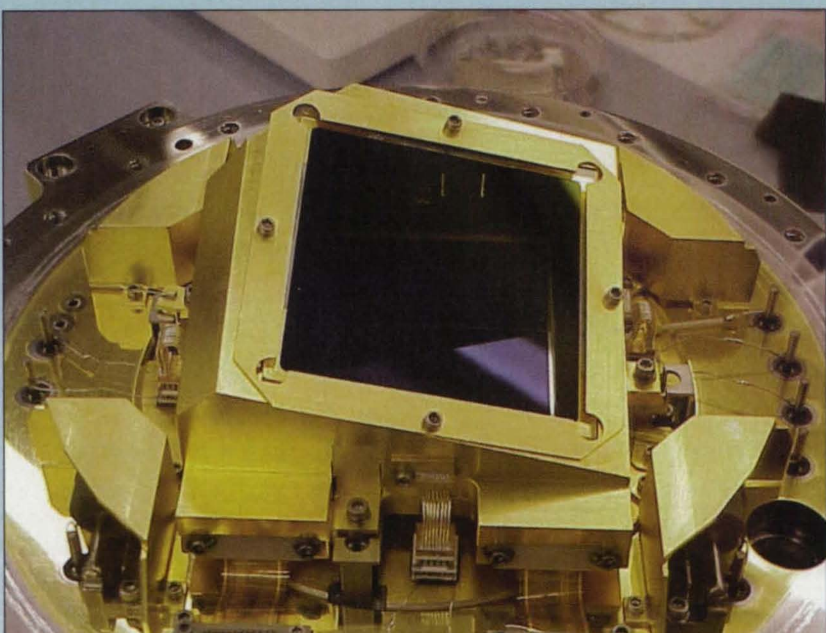
For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. See page 10 for a list of office contacts.

Application Briefs

Imaging Technology Upgrade Improves Hubble Space Telescope

Charge-coupled device (CCD) technology
Scientific Imaging Technologies, Inc. (SITe)
Tigard, OR
(503) 431-7199
www.site-inc.com

Launched in orbit in April 1990, the Hubble Space Telescope has provided astronomers and other researchers with reams of data and spectacular images of celestial bodies. In March, the Space Shuttle Columbia began an 11-day mission to upgrade several systems on the Hubble Space Telescope, including installation of an Advanced Camera for Surveys (ACS), which utilizes imaging technology developed by Scientific Imaging Technologies, Inc. (SITe). The SITe sensor was chosen to replace one of the company's earlier imagers that has operated on the Hubble since its refurbishment in 1997.



SITe's Wide Field Channel (WFC), one of three imaging channels comprising the Advanced Camera for Surveys (ACS).

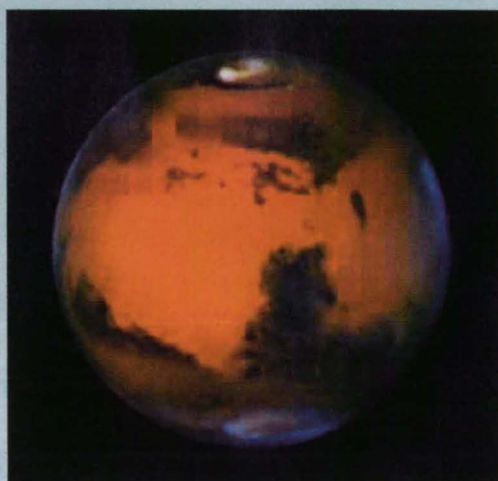
The ACS will replace the Faint Object Camera, the last of the original cluster of axial instruments on the Hubble. The three-meter-long ACS contains three imaging channels, two of which utilize SITe technology. The Wide Field Channel contains two SITe 2K × 4K chips that form a 4K × 4K mosaic; and the High Resolution Channel uses a single 1K × 1K SITe device.

The new technology will enable the Hubble to see farther, more clearly, and in greater detail than ever before. The ACS will double Hubble's field of view and enhance its image quality. The new camera will be used to map the distribution of dark matter, detect the most distant objects in the universe, and search for planets and galaxies.

This technology is enabled by the use of charge-coupled devices (CCDs), which replace vacuum tube-based imagers and film used in conventional cameras. Combined with optics, a cooling system, and operating electronics, these microchips produce high-resolution images by turning light into a stream of electronic signals, which can be recorded and displayed on a computer or television screen. By using CCD technology, it is estimated that the Hubble's imaging system will be 10 times more powerful than its current system.

SITe's CCD technology incorporates a proprietary process for thinning and strengthening the substrate to accommodate back-illumination of the pixels, a process that yields devices with high quantum efficiency (QE) over a range of wavelengths from near-infrared to ultraviolet. QE — or light-detection efficiency — measures the percentage of incident photons a CCD can detect. When configured with an anti-reflective coating, a thinned, back-illuminated CCD can deliver QE in excess of 90 percent.

When the photon falls on the CCD, it is absorbed and generates an electron. These electrons are collected in the "bucket" nearest the point where the photon was absorbed. The number of electrons collected in a pixel depends upon how many photons fall on that pixel. After the camera shutter closes, the number of electrons in each pixel are measured and a voltage proportionate to that number is generated. That voltage can be amplified, digitized, stored, and displayed.



After its initial refurbishment in 1997, the Hubble obtained this image of Mars, the sharpest view of the Red Planet ever taken from Earth.

In 1997, SITe's technology deployed on the Hubble was applied to an early-detection breast biopsy system currently used in hospitals worldwide. SITe CCDs also are used in protein crystallography and in the development of new drugs and therapies. Other application areas include manufacturing quality control, environmental monitoring, and security inspection and surveillance.

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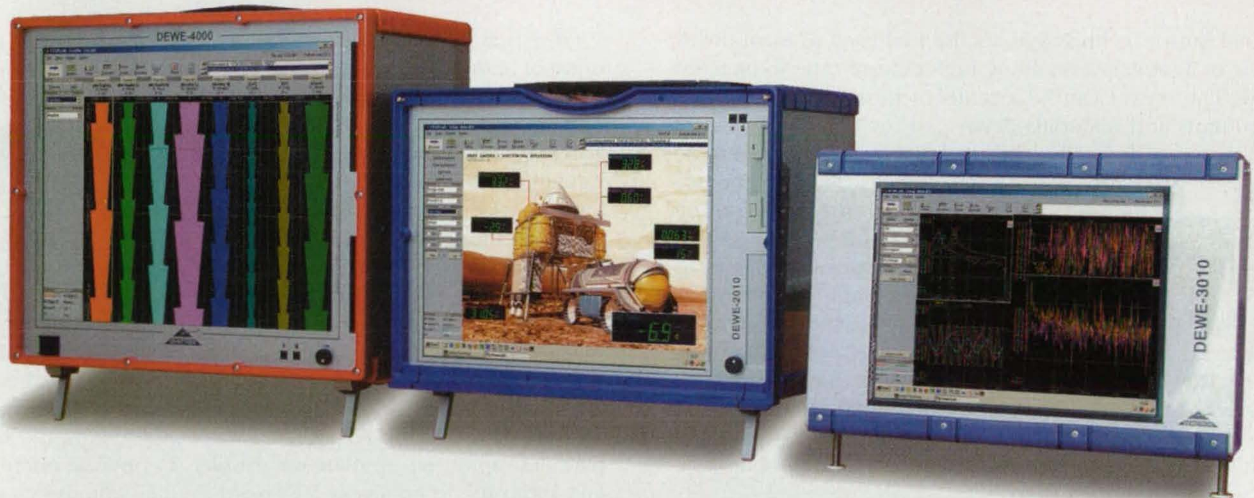


Above left to right – the DEWE-4000, DEWE-2010, and DEWE-3010 portable PC Instruments

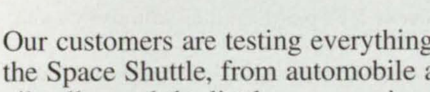
Our customers are testing everything from train cars to the Space Shuttle, from automobile airbags to oilwells...and the list keeps growing. Why? Maybe it's our plug-in signal conditioners that allow connection of *any signal, any sensor*. Or perhaps it's the fact that Dewetron systems are built on an open-architecture, COTS* computer platform, allowing easy upgrades and compatibility with all Windows® software and hardware.

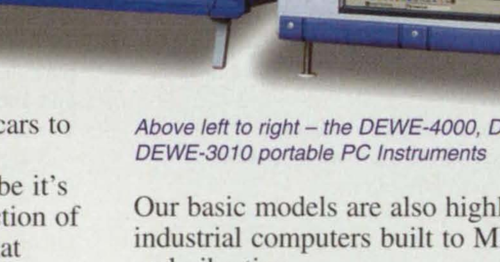
Or it could be our software–so easy to use and yet so powerful–with brilliant on-line displays, full-color printing and one-click export to Excel®, MatLab®, ASCII, and several other popular formats. Of course, Dewetron machines are perfect platforms for LabVIEW® development, and they already include a National Instruments® A/D card connected to our high-isolation plug-in signal conditioners!

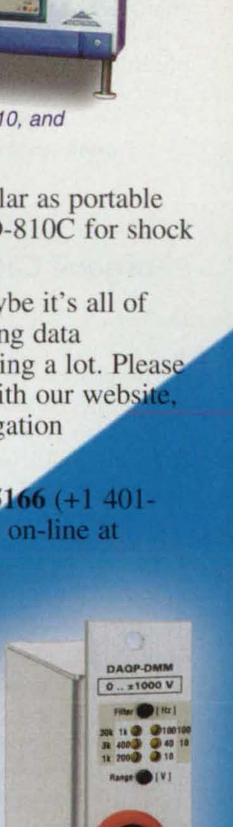
Our basic models are also highly popular as portable industrial computers built to MIL-STD-810C for shock and vibration.

It could be any of these things - or maybe it's all of them. The bottom line is, if you're doing data acquisition any other way, you're missing a lot. Please take a look at Dewetron today. Start with our website, or give us a call and arrange a no-obligation demonstration at your facility.

Contact us today toll-free at **877-431-5166** (+1 401-364-9464 outside the USA), or visit us on-line at **www.dewamerica.com/ntb**







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Technologies of the Month

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For more information on these and other new, licensable inventions, visit www.nasatech.com/techsearch

Using Conductance/Capacitance to Measure Fuel Mixture Ratios

Thilo Schwoebel, Robert Bosch GmbH, Germany

A fuel sensor technology uses the fuel itself to form the dielectric of a capacitor enabling fuel mixture ratio to be maintained. The sensor can be assembled using ceramic-molded components and materials developed for thick-film technology. The measuring cell is composed of a cavity formed by ceramic carriers. The fuel mixture flows through the cavity and becomes part of the evaluation circuit. The measuring cell can include a second cavity that is closed and contains a reference medium. The capacitors are part of the evaluation circuit that notes any capacitance changes as the conductance of the fuel mixture changes.

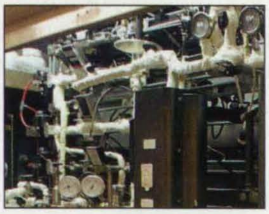
The sensor is suitable for internal combustion engine applications, including electrical generators, automobiles, aircraft, and liquid-fueled rockets.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/schwoebel.html
Email: nasatech@yet2.com
Phone: 617-557-3837

Phosgene Catalyst Reduces Toxic By-Product

DuPont

The process used to manufacture phosgene, a key ingredient in the production of polyurethane and polycarbonate resins, also creates carbon tetrachloride (CCl_4), an ozone-depleting substance. Federal and state environmental guidelines require that CCl_4 be removed from the product stream to prevent environmental contamination. If it cannot be controlled at the source during production, expensive "end-of-the-pipe" equipment has to be installed and maintained by the manufacturers. Researchers at DuPont have developed a phosgene catalyst that reduces emission of CCl_4 by more than 80%.



It was discovered that chlorine, one of the ingredients used to make phosgene, reacted with the granulated carbon catalyst to produce high levels of CCl_4. To repair this, a replacement catalyst was utilized that can be applied to commercial pressurized tube bundle reactors. Benefits include a reduction of process downtime because the new catalyst does not deplete as rapidly as the former.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/dupont-phosgene.html
Email: nasatech@yet2.com
Phone: 617-557-3837

Water-Wash Paint Overspray Solution Reduces or Eliminates Paint Waste

Caterpillar

Overspray of protective coatings may cost manufacturers half or more of their purchased paint. The majority of today's water-wash paint lines use forced air to direct "live" airborne droplets of paint through a cascading water curtain just prior to advancing to the system's exhaust stacks. An alternative to this method uses *hydrophobic fumed silica* (HFS) particles in conjunction with the water-wash system design that do not mix with water. HFS particles require no technical labor for chemical titrations, booth water, or additives. When droplets of "live" paint are introduced to the HFS-treated water-wash booth, the HFS particles rapidly encapsulate the droplets by physical phenomena and result in non-tacky HFS-paint agglomerations that can be manually removed.

It is possible to process HFS detackified paint "sludge" and re-use it in paint or other products utilizing similar chemistry. The detackification and recovery technology has proven applicable to all solvent-based paints on which it has been tested, including automotive and construction equipment.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/caterpillarHFS.html
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Communication Software Securely Bridges Diverse Firewalls

Science Applications International Corporation

Firewall transit communication has been limited to participants on opposite sides of single firewalls, and there has been no "off-the-shelf" technology offering seamless and secure cross-firewall communication. An application called SD-Link features an Internet-based intermediate server that maintains connections and exchanges data between clients behind separate firewalls.

SD-Link permits worldwide communication across multiple private and public networks while maintaining security through end-to-end encryption and authentication. The application can communicate either directly to an SD-Link communication component at any seat of a standalone network, or through an SD-Link-enabled applet for browser-based operation.

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NASA Tech Briefs Presents 2001 Product of the Year Awards

The seventh annual *NASA Tech Briefs* Readers' Choice Product of the Year Awards were presented March 18 at a special reception at the John Hancock Center in Chicago, in conjunction with the kickoff of the National Manufacturing Week show. The awards, chosen by the more than 195,000 readers of *NASA Tech Briefs,* recognized the Gold, Silver, and Bronze winners, as well as nine Product of the Year Finalists.

Each month, the editors of *NASA Tech Briefs* choose a Product of the Month, a product that exhibits exceptional technical merit and practical value to our readers. All 12 products are placed on a ballot and readers vote for the most innovative product introduced to the engineering community during the year. The product receiving the most votes is named the Gold Winner and Product of the Year.

VX Corporation's vice president of sales & marketing, Bob Fischer, accepts the 2001 Gold Award for Product of the Year.

Product of the Year Finalists from Dolch Computer Systems join *NASA Tech Briefs'* editor and associate publisher, Linda Bell. From left: Michael Kadri, vice president and general manager for Dolch's Canadian offices; Jim Ciardella, president of Dolch; and Tom Brassil, vice president of sales and marketing.

The 2001 Gold Award for Product of the Year was presented to VX Corporation of Palm Bay, FL, for its VX CAD/CAM Version 5 software. The top prize was accepted by Bob Fischer, vice president of sales & marketing for VX, who commented that "The readers of *NASA Tech Briefs* are among the most technically sophisticated and influential people in the engineering world. This recognition is incredibly gratifying and really underscores how our approach to CAD/CAM solves difficult design and manufacturing problems for the most exacting users."

2001 Product of the Year Award Winners: (From left) Bronze Award recipient Ray Almgren of National Instruments; Bob Fischer of VX Corp., Gold Winner; and NTB associate editor, Laura Raduta, accepting for Silver Winner, MathSoft Engineering & Education.

Version 5 of VX CAD/CAM — last August's Product of the Month — is a design-through-manufacturing package that integrates product design and manufacturing to eliminate the gap between CAD and CAM packages. Version 6 of the software was introduced at National Manufacturing Week and is now available (www.vx.com).

The Silver Award was won by MathSoft Engineering & Education of Cambridge, MA, for Mathcad® Client collaborative math software. The award was accepted by Laura Raduta, Associate Editor of *NASA Tech Briefs.* Last October's Product of the Month, Mathcad Client was designed for sharing and collaborating on Mathcad-created content across and throughout an organization. It provides a tool for sharing math on the Internet, as well as via corporate extranets and intranets. (www.mathsoft.com)

National Instruments of Austin, TX, took home the Bronze Award for Measurement Studio™ 6.0, a set of measurement tools that engineers can use to create test, measurement, and control applications in various programming languages. Ray Almgren, vice president of product strategy for National Instruments, accepted the award. Measurement Studio lets users display data on real-time 3D or 2D graphs and charts that can be annotated to explain significant dips or spikes in the data. (www.ni.com)

The following companies were honored as Product of the Year Finalists for 2001:

- Dolch Computer Systems (Fremont, CA) for the FlexPAC™ rugged portable computer (www.dolch.com)
- ifm efector (Exton, PA) for the OJ Series photoelectric sensors (www.ifmefector.com)
- iOtech (Cleveland, OH) for the DaqBoard/2000c™ data acquisition boards (www.iotech.com)
- Mountz (San Jose, CA) for the Wizard torque & force analyzer module for PDAs (www.etorque.com)
- OMEGA Engineering (Stamford, CT) for the OM DL-Series portable dataloggers (www.omega.com)
- think3 (Santa Clara, CA) for thinkdesign 6.0 CAD software (www.think3.com)
- Vistagy (Waltham, MA) for EnCapta™ collaborative engineering software (www.vistagy.com)
- Wavetek Meterman Test Tools (Everett, WA) for Meterman test & measurement instruments (www.metermantesttools.com)
- Wolfram Research (Champaign, IL) for CalculationCenter technical calculation software (www.wolfram.com)

(All photos by Michael J. Kardas, Kardas Photography, Chicago, IL)

E-Engineering: Defining the Market

"The notion of actually doing engineering on-line or via the Internet is just starting to take hold," according to Jim Schultz, director of e-business and additional sales channels for MSC Software. So as this idea of collaborative engineering, or e-engineering, continues to become a more clearly defined market, vendors are struggling to differentiate themselves, and users are struggling through the maze of available products.

With all of the product lifecycle management (PLM), viewing, meeting, and other Internet-based engineering tools out there, what's really working? What products are manufacturers using in a practical way today?

"We recognize that there's a new way of designing, developing, and manufacturing products," said Mike Grandinetti, senior vice president and chief marketing officer for PTC's Windchill Business Unit. "The old way was that everybody worked in the same building and could walk down the hall to talk to their colleagues. The world doesn't work that way anymore. Engineering has always been a team sport, but companies really haven't given their engineering and manufacturing people the tools to collaborate," Grandinetti added.

3D TeamWorks from SolidWorks is an on-line environment where users can conduct real-time design reviews and coordinate team activities.

"Where I don't see a lot of success among the e-engineering based products is where they try to tie together disparate disciplines," said Jim Tung, chief market development officer for The MathWorks, a supplier of technical calculation software. "Some vendors feel that the correct way to approach Internet-based collaboration is to come up with Web-based extractions of specific design elements within a tool. Their technology becomes the way that the extraction is communicated from tool to tool," Tung added. "That almost never succeeds."

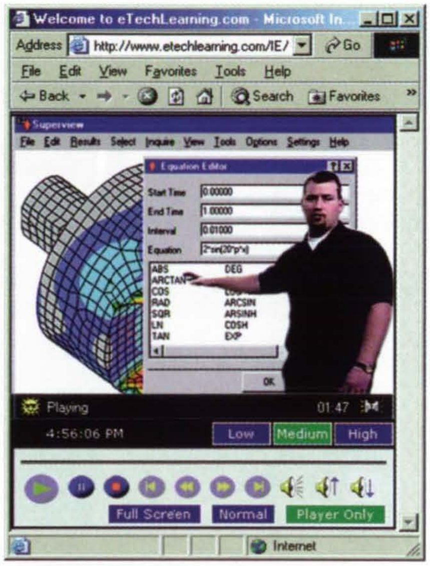
Providing engineers with such tools at their fingertips is where the evolution begins, said Schultz. "This will be facilitated by improvements to the Web itself, including the employment of smart agents. We want to create more Web-enabled access to tools, provide consultant services, and take these complicated tools and make them more user-friendly."

User-friendly is not a term generally equated with Internet-based engineering tools. That's part of the reason why only the most basic of collaborative products are being used today, according to Greg Milliken, vice president of marketing for Alibre, maker of Alibre Design, a data sharing, CAD, and real-time collaboration system.

"Generally, only very simple virtual meetings and some very limited client-server data access or visualization is being used to any significant extent today," Milliken said. "The biggest thing used is probably just e-mail — sending drawings or documents back and forth to be reviewed and then sent back. In the next five years," he continued, "individuals will be empowered to connect and share data with anyone they want, since the tools will be so inexpensive, everyone will have them."

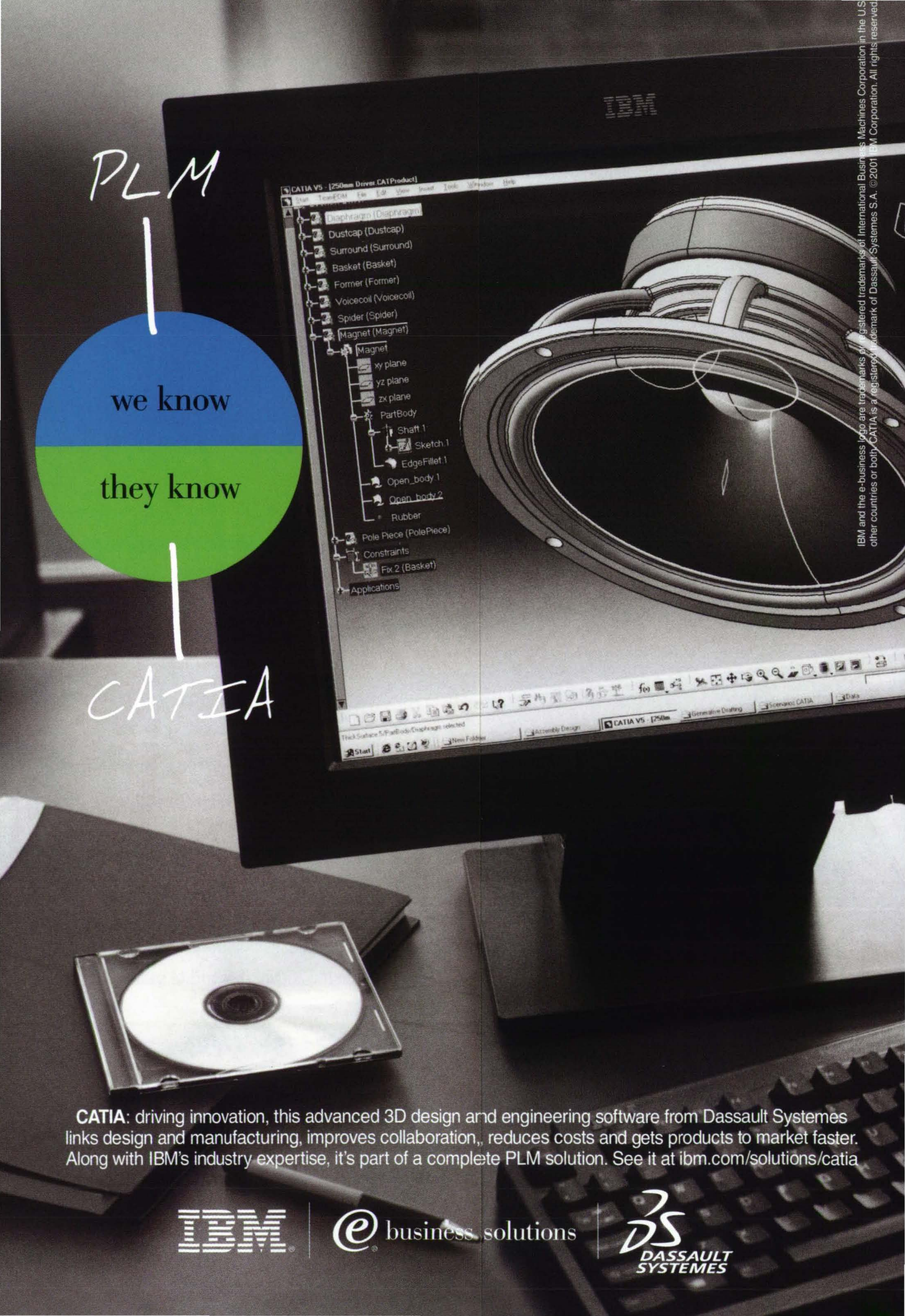
E-mail as a manufacturer's only collaboration tool just won't cut it, said Chris Will, marketing director of collaboration products for EDS PLM Solutions. "Engineers spend over 75% of their day trying to find the right information," he said. "When you think about the complexity of these distributed collaborative teams, and trying to synchronize to make sure everybody's working the right sets of information, it's a major challenge to do without a collaboration tool. If I'm e-mailing files, how do I know everybody's designing to the right information? Do they have to translate to some other format or CAD system?"

SolidWorks' product manager for collaboration products, Robert McDonald, said that his research with the SolidWorks customer base as far as what collaborative products they're currently using was very surprising. "We assumed our customer base knew as much as we do. But they have not even heard of simple things like WebEx to do collaboration. This space is so new that they're looking to their CAD vendor to be able to provide a solution they can understand." SolidWorks' latest offering in the collaboration space is 3D TeamWorks, a Web-based service through which design teams can review designs, share information, and troubleshoot problems.



Algor, Inc.'s Webcasting audio/video technology for distance learning and free, live software demonstrations enable education and customer support over the Internet.

Despite the fact that e-mail today seems like a "stone-age" tool, the traditional methods of communication, such as faxes, phone calls, web conferencing, and yes, e-mail, are still the most-used forms of collaboration. More generic collaboration tools like document-sharing products are at a 50% adoption rate, according to Grandinetti. "We're on the


PLM
we know
they know
CATIA
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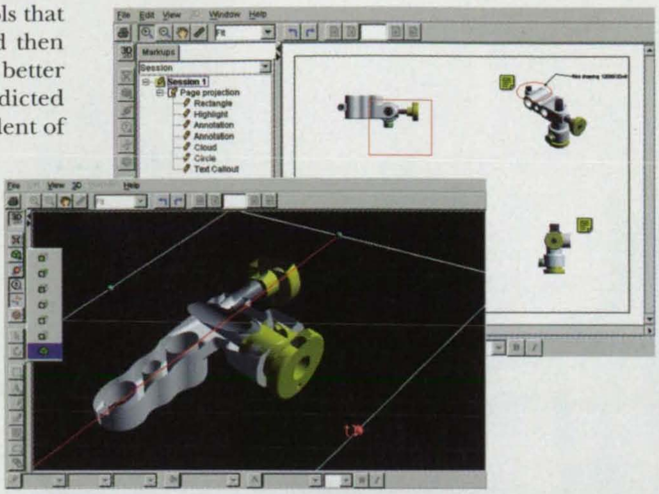
cusp of true collaborative engineering being commonplace," he said. "We're making the technology much more accessible to everyone."

But does accessibility equal widespread use? "The grass-roots tools that are useful to one engineer, and then to groups of engineers, have a better chance of taking hold," predicted Allen Razdow, senior vice president of strategic planning for MathSoft Engineering & Education, which has added PDM functionality on top of its Mathcad software. "Access to the Internet tends to be more tightly controlled in engineering environments," he added. "The dot-com model of getting on the Web and downloading your favorite tool doesn't work well in more controlled industries where the network has to be carefully managed and accessed."



In this image from Spicer's ViewCafe viewing tool, a cross-sectioned 3D model is shown in the ViewCafe applet. The window behind shows the same model in 2D-projection mode with markups.

There is a category of products that work, according to Robert Kross, vice president of Autodesk's Manufacturing Division. Those are asynchronous tools. "There are a lot of synchronous tools out there, but they require both parties to be on the Internet at the same time, working together. That's not the way people work today, especially in different time zones," Kross said.

"The Internet is still used primarily for information exchange," explained Bob Williams, product manager for ALGOR, Inc., supplier of finite element analysis and mechanical event simulation software. "Among other things, we utilize the Internet to offer distance learning through Webcasting technology; live, Internet-based product demonstrations; and automatic generation and publishing of HTML reports to the Internet that include Web-based graphics and animations."

Many organizations don't want to share their data during the design phase, said George Schildge, vice president of corporate communications for CoCreate, which supplies the OneSpace suite of collaborative product development tools. "Collaboration is about teamwork and sharing ideas, but many organizations are working in the old-school model of 'I'll create it and when I'm done, I'll throw it over the fence to manufacturing and let the engineers deal with it.'"

Part of the evolution of Internet-based engineering tools will occur as the Internet itself continues to evolve. Said Williams, "There are ongoing efforts to continually improve the backbone of the Internet, and as that happens, you'll start to see additional types of engineering activities or other software usage becoming more prevalent. There are performance issues now, and most of them are tied to the fact that the Internet itself needs to be expanded," he added. "We're planning to provide software in real time over the Internet through a browser, so instead of purchasing the software, you're leasing it to get a specific application done."

"The customers who are driving collaboration are driving it from a product standpoint," said Michael Wheeler, vice president and general manager of the mechanical business unit for ANSYS, which supplies simulation software. "Our products are becoming more Web-enabled due to customer demand. People are overcoming their fears of transmitting company data over the Internet," Wheeler added.

The Internet began — and continues to be — a communication device that lends itself well to collaborative engineering. But before that can be commonplace, many changes need to take place, including distinguishing what products are out there and how they're different.

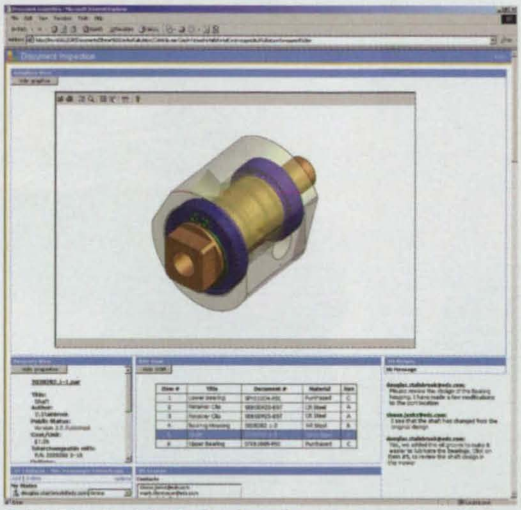
Products, Products Everywhere

Are collaborative engineering products still too vague and confusing for many manufacturers to understand? Yes, said Alibre's Milliken. "Most of the large-scale expensive and complicated enterprise systems are not being used in a big way — they have yet to be proven. Many think it's just the same old thing with a different name."

Alibre believes that the broad categories of PLM or collaborative product commerce (CPC) are too vague, Milliken explained. The CPC space, however, is exactly where companies like Web4/netGuru have made their home. Their e-Review product is a Web-based, real-time collaboration tool for document review and markup that supports more than 150 file formats natively.

"We've got people that will design on a particular platform, and they'll use a collaborative engine to share that information," said Ben Parikh, director of corporate sales and marketing for Web4. "In the future, we'll probably have real-time interactive design on-line without having to go back to your desktop and make changes."

A relatively new entry into the viewer category is Spicer Corp., which introduced ViewCafe™ 2.1. The Java-based tool lets engineers conduct document view, markup, and collaborative review sessions for over 150 file formats, including CAD, Microsoft Word and Excel, raster, vector, and PDF, through a Web browser.



Solid Edge Insight Technology from EDS enables viewing and rotating of the most current 3D model without engineering experience. Part properties, a Bill of Materials, and instant messaging also are available.

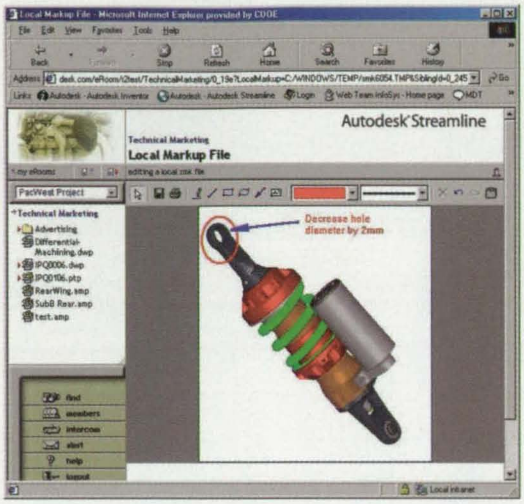
Proficiency offers its Collaboration Gateway that enables manufacturers to share product design information, even if it was created using different mechanical design products. It lets users of four mechanical CAD systems — Dassault Systemes' CATIA, PTC's Pro/ENGINEER,

(Continued on pg. 32)


too few
software seats
insufficient
compute time
simulation
uncertainties
incorrect
analysis
market window
closing
need larger
team
not enough
experts

and EDS's Unigraphics and I-DEAS — exchange digital assembly or part models without having to learn another tool or lose data.

Another product category tossed into the mix is the ASP (Application Service Provider) model. ANSYS's collaborative product offering, eCAE, is similar to an



Autodesk's Streamline is a hosted service for sharing digital design data so project members can view graphics, parts, and assemblies embedded in CAD files.

ASP, according to Wheeler. "It's pay-as-you-go simulation that has been created in response to our customers' need for software on the basis of service," Wheeler explained. "As CAE is implemented into the design process, engineers are solving larger simulations. In those cases, they can't be handled on PCs like the initial simulations they were running. So, the eCAE service has an extremely large compute farm of CPU resources."

MSC Software also provides on-demand use of their software. According to Schultz, customers can access MSC software anywhere in the world within 15 minutes of their purchase order being validated. The company sells millions of those licenses per year. MSC's server-based service is the SimulationCenter, which allows engineering and simulation from remote locations onto MSC's server. "Users take their CAD model, download it to us via the Internet, and we run the model simulation on our servers," Schultz explained. "Customers can also access MSC directly and engage in professional services for CAD design or repair using our employees and engineers at various levels."

Companies like ALGOR are working hand-in-hand with CAD companies to make their simulation and analysis products more Web-friendly. "Collaborative tools such as PDM applications are being integrated into the CAD solid modelers since users of those products are often making a large number of design changes," said ALGOR's Williams. "So, we have made our FEA models and results directly associated with their CAD data so the user can more easily manage updates to the geometry and analysis data related to their designs."

CAD companies like EDS are providing their own collaboration tools that tie into their core CAD product — or another CAD product. Chris Will explained that Team-Center Engineering lets users manage other related information besides CAD data, and provides a configured design, integrating it to the Unigraphics CAD product.

Keeping track of the myriad of available products isn't easy — even for the vendors. Said Williams, "It's hard to keep up with the buzz words even when you work with them all the time. Vendors have to simply focus on the principle that when users have a streamlined process and the tools to support that process, they are going to get products to market faster."

Why the Web?

Amid the confusion of so many types of products, the relative infancy of the market, and the unwillingness of customers to try these unproven tools, how does a vendor convince a manufacturer to take the plunge and employ Web-based engineering tools? Said MSC's Schultz, it's relatively easy.

"Vendors need to articulate the benefits. The story has to be, 'do you have tools and processes that show engineers they can have a robust system they can interface over the Web that is tailored for them, as opposed to just generic things?'" Engineers, Schultz said, are creatures of habit. "There are cultural challenges we're aware of that have to be answered to help them feel comfortable in a virtual world."

The common mantra is reduced time to market and helping manufacturers understand the value of collaborative engineering in shaving product development costs and time.

"If customers can look at competitors that are using these systems effectively or see companies in similar industries using them with quantifiable benefits, a picture is worth a thousand words," explained PTC's Grandinetti. "It provides comfort and security to the manufacturing buyer."

Williams believes that ALGOR's users already understand the values and principles behind these tools, but they need to incorporate the ones that work best. "It sounds simple," he said, "But it comes down to the individual company. In the end, it's the user who will tell you what they need to be effective.

"A small machine shop with four engineers probably would find it not to be cost-effective to have a PDM application that forces them to use a specific CAD package or a specific analysis tool," Williams continued. "They may just need nothing more than the ability to get information fast or talk to more experienced engineers through an interactive users' forum. More sophisticated technology may be cost-prohibitive."

Ease of use and the practical benefits achieved through collaborative engineering products remain the strong selling points, according to SolidWorks' McDonald. "If we don't make it easier for users to do the things they're doing now, they won't be interested in these tools. If I can improve the way they communicate now, then we'll succeed."

And vendors have recognized that the Internet is the way to go to help their customers succeed. "One of the things that's different is that a year ago, every company would have talked about their Internet strategy," said Autodesk's Kross. "Now, we view the Internet as a vehicle. Who doesn't have something that will work on the Internet? It's another medium with unique advantages, and it's fundamentally game-changing. It does change the world."

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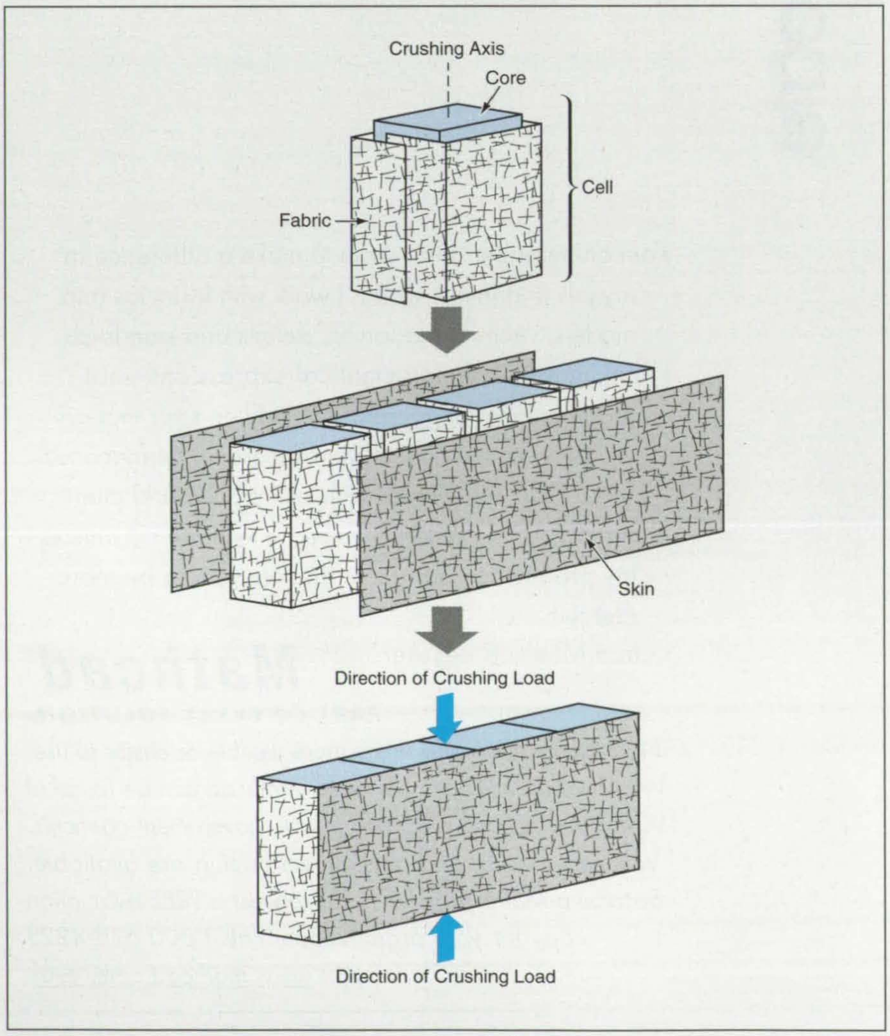
Composite-Material Structures for Absorbing Crash Energy

These structures can be fabricated relatively easily and inexpensively.

Langley Research Center, Hampton, Virginia

Improved lightweight composite-material structures have been invented to protect persons and equipment during aircraft and ground-vehicle crashes. These structures are designed to hold their initial shapes and sustain rated loads under normal operating conditions and, during crashes, to undergo sustained deformation with high stroke efficiency at tailored crush loads to absorb kinetic energy. The advantages offered by these structures over prior crash-energy-absorbing structures, including composite-material ones, are that these structures can be fabricated by use of relatively simple, cost-effective techniques and the designs of the structures can readily be adapted to a variety of applications.

One example of design and fabrication of a structure of this type is that of a simple rectangular parallelepiped beam comprising a stack of cells (see figure). The cell cores are designed to be crushed along their longest axes. First, the cells are fabricated, starting from blocklike cores, which could be hollow and/or made from a closed-cell, low-density, rigid polymeric structural foam. Each core is wrapped with a woven fabric or other continuous fiber reinforcement. The wrap is impregnated with a suitable matrix resin by use of any of a number of established techniques.



Foam Blocks Designed To Be Crushable along their vertical axes are wrapped with resin-impregnated fabric, then stacked horizontally. The stack is overwrapped with another resin-impregnated fabric, and the resins are cured to form a unitary beam.

The cells are stacked in the desired orientation along the intended longitudinal axis of the beam. In a typical application, the beam might be intended to serve as a subfloor structure in an aircraft, where it could protect occupants against excessive vertical crash loads by yielding vertically: in this case, the preferred orientation of the long axis of each cell in the stack is vertical. Skins of resin-impregnated continuous fiber reinforcement, possibly similar to those of the individual cells, are wrapped around the stack, holding the cells together firmly. Then the resins are cured, yielding a unitary, rigid structure, wherein the bonded skins at the interfaces of adjoining cells constitute additional transverse reinforcements. If there is a requirement that the beam retain its post-crash integrity, then the skin should be composed of tough fibers (e.g., an aromatic polyamide or polyethylene fabric).

Structures of this type are not limited to a simple beam design and fabrication sequence like those described above. Structures can have more complex regular or irregular shapes, can be fabricated in different sequences, and can be made from different foams, fibers, and resins. The materials, dimensions, fiber orientations, and other design parameters can be selected to obtain specified direction-dependent crushing characteristics while satisfying shape and load-bearing structural requirements during normal operation.

This work was done by Sotiris Kellas for and Huey Carden of **Langley Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*

This invention has been patented by NASA (U.S. Patent No. 5,746,537). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Rheal Turcotte, Technology Commercialization Program Office, NASA Langley Research Center at (757) 864-8881 or e-mail at r.p.turcotte@larc.nasa.gov. Refer to LAR-15397.

Improved Conversion Coating for Protection of Metals

This method is an environmentally friendly alternative to older processes.

John H. Glenn Research Center, Cleveland, Ohio

A simple, cost effective, environmentally friendly conversion-coating process has been developed for protecting a variety of metals against wear and corrosion and to increase adhesion of paints. This process results in the deposition of a thin, adherent coats of iron phosphate on treated metal substrates. This process is expected to supplant the environmentally hazardous chromate-based conversion-coating process heretofore used in the automotive and aerospace industries. It is also expected to supplant a process in which bearing races made of 440C stainless steel are pretreated with tricresyl phosphate.

In the improved process, a precleaned metal substrate of 440C stainless steel or other metal is dipped into a solution comprising 1 weight percent of Durad (or equivalent phosphate ester) and 1 weight percent of ferric acetylacetonate in ethanol. The dip is done at room temperature for 1 minute. After the dip, the ethanol is allowed to evaporate, leaving a thin film of the phosphate ester and the ferric acetylacetonate. The substrate is then inserted for 1 minute in an oven that has been preheated to ≈300 °C. This heating causes the formation of a thin film of iron phosphate, as confirmed by x-ray photoelectron spectroscopy.

This work was done by Wilfredo Morales of **Glenn Research Center.**

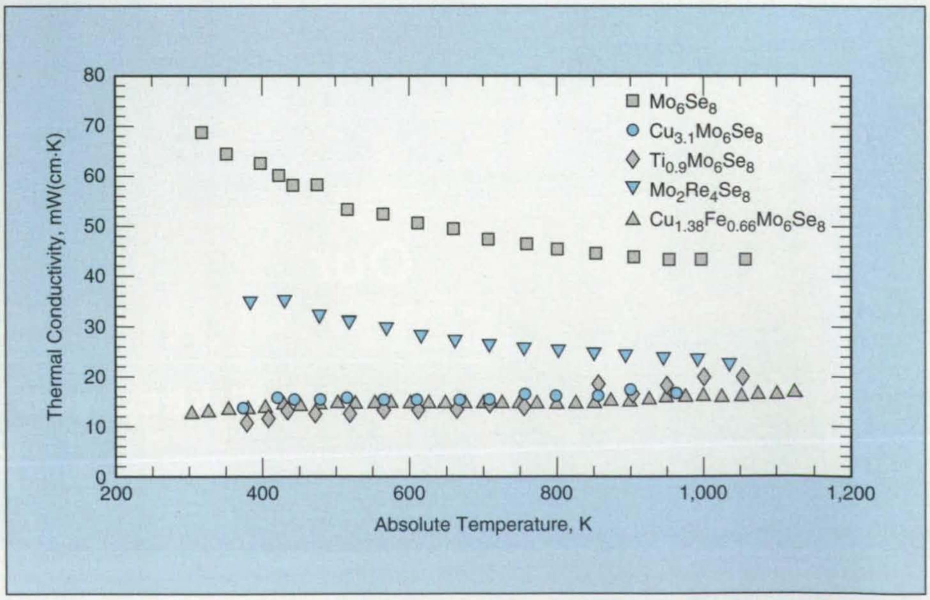
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16680.

Chevrel Phases as Potential Thermoelectric Materials

Scattering of phonons by loosely bound atoms reduces thermal conductivity.

NASA's Jet Propulsion Laboratory, Pasadena, California

Crystalline phases of compounds of general composition (Cu_w, Cu_xFe_y, or Ti_z)Mo_6Se_8 [where $w<4$, $x<2$, $y<1$, and $z<1$] have been investigated for potential utility as thermoelectric materials for generation of electric power from waste-heat and other thermal sources. These phases are a subset of a set of ternary chalcogenide compounds named Chevrel compounds or phases after one of the researchers who first synthesized them in 1971. As explained below, relatively low thermal conductivity is an outstanding aspect of these compounds that makes them potentially attractive for thermoelectric applications.



Thermal Conductivities (as functions of temperature) of several candidate Chevrel phases were measured. Also shown for comparison are the corresponding quantities for Mo_6Se_8 and $Mo_2Re_4Se_8$.

The figure of thermoelectric merit of a given material at a given temperature T is commonly denoted as ZT and is given by the equation $ZT = \alpha^2 T/\rho\lambda$, where α is the Seebeck coefficient, ρ is the electrical resistivity, and λ is the thermal conductivity of the material at that temperature. Hence, as part of an effort to develop a material of large ZT, one should seek to minimize λ.

The present investigation is an extension of recent research on other thermoelectric materials that belong to a class of compounds called "rattling" semiconductors. The crystalline lattices of these materials contain cavities large enough to accommodate a variety of additional atoms, which are bound relatively loosely and are thus somewhat free to move around ("rattle"). It had been suggested that in such compounds, the rattling of the additional atoms would contribute more to scattering of phonons than to scattering of electrons and holes. Consequently, the rattling could be expected to contribute more to thermal than to electrical resistivity — an effect that would be favorable for obtaining a large value of ZT.

The (Cu_w, Cu_xFe_y, or Ti_z)Mo_6Se_8 Chevrel phases belong to the class of rattling materials. The electronic and thermal properties of these compounds could, potentially, be tailored through careful selection of the amounts and the manner of incorporation of the filling elements (Cu, Cu with Fe, or Ti). The compounds investigated thus far are $Cu_{3.1}Mo_6Se_8$, $Cu_{1.38}Fe_{0.66}Mo_6Se_8$, and $Ti_{0.9}Mo_6Se_8$, which exhibit p-type electrical conductivity and relatively low values of thermal conductivity (see figure). Of these compounds, the best was found to be $Cu_{1.38}Fe_{0.66}Mo_6Se_8$, for

which ZT = 0.6 at a temperature of 1,150 K. This value of ZT is comparable to the ZT values of Si-Ge alloys in the same temperature range. One drawback of these three compounds has been low charge-carrier mobility. It will be necessary to increase charge-carrier mobilities in order to obtain ZT values greater than those of state-of-the-art thermoelectric materials. Research toward that end was underway at the time of reporting the information for this article.

This work was done by Thierry Caillat, Jean-Pierre Fleurial, G. Jeffrey Snyder, and Alexander Borshchevsky of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*

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Refer to NPO-21012, volume and number of this NASA Tech Briefs *issue, and the page number.*

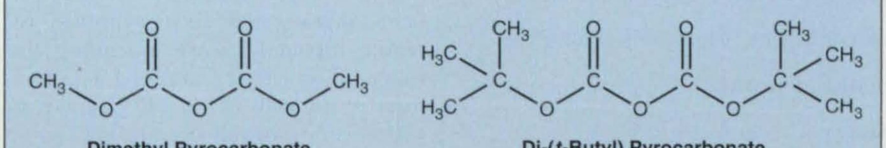
Alkyl Pyrocarbonate Electrolyte Additives for Li-Ion Cells

Beneficial properties of films that form on carbon anodes are enhanced.

NASA's Jet Propulsion Laboratory, Pasadena, California

Alkyl pyrocarbonates have been found to be useful as electrolyte additives for improving the low-temperature performances of rechargeable lithium-ion electrochemical cells. The beneficial effects of these and other additives have been investigated, along with various electrolyte formulations, in continuing research directed toward extending the range of practical operating temperatures from the present lower limit of –20 °C down to –40 °C, and even lower if possible. This research at earlier stages was reported in a number of *NASA Tech Briefs* articles; namely, "Update on Electrolytes for Low-Temperature Lithium Cells" (NPO-20407), Vol. 24, No. 1, (January 2000), page 56; "Lithium Alkoxide Electrolyte Additives for Lithium-Ion Cells" (NPO-20607), Vol. 25, No. 6 (June 2001), page 52; "Aliphatic Ester Electrolyte Additives for Lithium-Ion Cells" (NPO-20601), Vol. 25, No. 6 (June 2001), page 53; and "Ethyl Methyl Carbonate as a Cosolvent for Lithium-Ion Cells" (NPO-20605), Vol. 25, No. 6 (June 2001), page 53.

To recapitulate from the cited prior articles: the loss of performance with decreasing temperature is attributable largely to a decrease of ionic conductivity and the increase in viscosity of the electrolyte. What is needed to extend the minimum operating temperature from –20 °C down to –40 °C is a stable electrolyte solution with relatively small low-temperature viscosity, a large electric permittivity, adequate coordination behavior, and appropriate ranges of solubilities of liquid and salt constituents. Whether the anode is made of graphitic or non-graphitic carbon, the surface film acts as a solid/electrolyte interface (SEI), the nature of which is critical to low-temperature performance. Desirably, the surface film should exert a chemically protective effect on both the anode and the electrolyte, yet should remain conductive to lithium ions to facilitate



Dimethyl Pyrocarbonate   Di-(*t*-Butyl) Pyrocarbonate

These **Alkyl Pyrocarbonates,** when used as additives to an optimized electrolyte formulation, have been found to improve the low-temperature performances of rechargeable lithium-ion cells by contributing to the formation of protective SEIs with increased ionic conductivities.

intercalation and deintercalation of the ions into and out of the carbon during discharging and charging, respectively.

One previously reported optimized electrolyte formulation is a 1.0 M solution of $LiPF_6$ in a ternary solvent that consists of equal volume parts of ethylene carbonate (EC), dimethyl carbonate (DMC), and diethyl carbonate (DEC). Also previously reported is the use of quaternary additives to this baseline optimized formulation to enhance low-temperature performance.

The present alkyl pyrocarbonate additives (see figure) to the baseline optimized electrolyte formulation promote the formation of protective and conductive SEIs on carbon anodes. The formation of such SEIs is believed to be facilitated by products (e.g., CO_2) of the decomposition of these additives. These decomposition products are believed to react to form Li_2CO_3-based films on the carbon electrodes. The improvement (relative to the baseline formulation) in interfacial properties resulting from the use of these additives is more evident at low temperature, where enhanced kinetics of intercalation and deintercalation of Li, higher ionic transport across SEIs, and increased discharge capacities with low overpotentials are observed. Also, the SEIs that form in the presence of these additives are more stable toward any further reduction of the electrolyte and thus more stable against growth to greater thicknesses; hence, they contribute to the cycle lives of the anodes.

This work was done by Marshall Smart, Ratnakumar Bugga, and Subbarao Surampudi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*

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Refer to NPO-20775, volume and number of this NASA Tech Briefs *issue, and the page number.*

Fluorinated Alkyl Carbonates as Cosolvents in Li-Ion Cells

These solvents offer advantages with respect to performance and safety.

NASA's Jet Propulsion Laboratory, Pasadena, California

Partially fluorinated alkyl carbonate liquid compounds have been found to be excellent electrolyte cosolvents for rechargeable lithium-ion electrochemical cells. The benefits afforded by these and other ingredients of electrolyte solutions in rechargeable Li-ion cells have been investigated in continuing research directed toward extending the range of practical operating temperatures of the cells (from +40 °C down to –40 °C, and possibly even as low as –60 °C). Fluorinated solvents were perceived to be especially attractive in that they will result in inherently safer cells, due to their low flammability. This research at earlier stages was reported in a number

of previous *NASA Tech Briefs* articles; namely, "Update on Electrolytes for Low-Temperature Lithium Cells" (NPO-20407), Vol. 24, No. 1, (January 2000), page 56; "Lithium Alkoxide Electrolyte Additives for Lithium-Ion Cells" (NPO-20607), Vol. 25, No. 6 (June, 2001), page 52; "Aliphatic Ester Electrolyte Additives for Lithium-Ion Cells" (NPO-20601), Vol. 25, No. 6 (June, 2001), page 53; "Ethyl Methyl Carbonate as a Cosolvent for Lithium-Ion Cells" (NPO-20605), Vol. 25, No. 6 (June, 2001), page 53; and "Alkyl Pyrocarbonate Electrolyte Additives for Li-Ion Cells" (NPO-20775), which precedes this article.

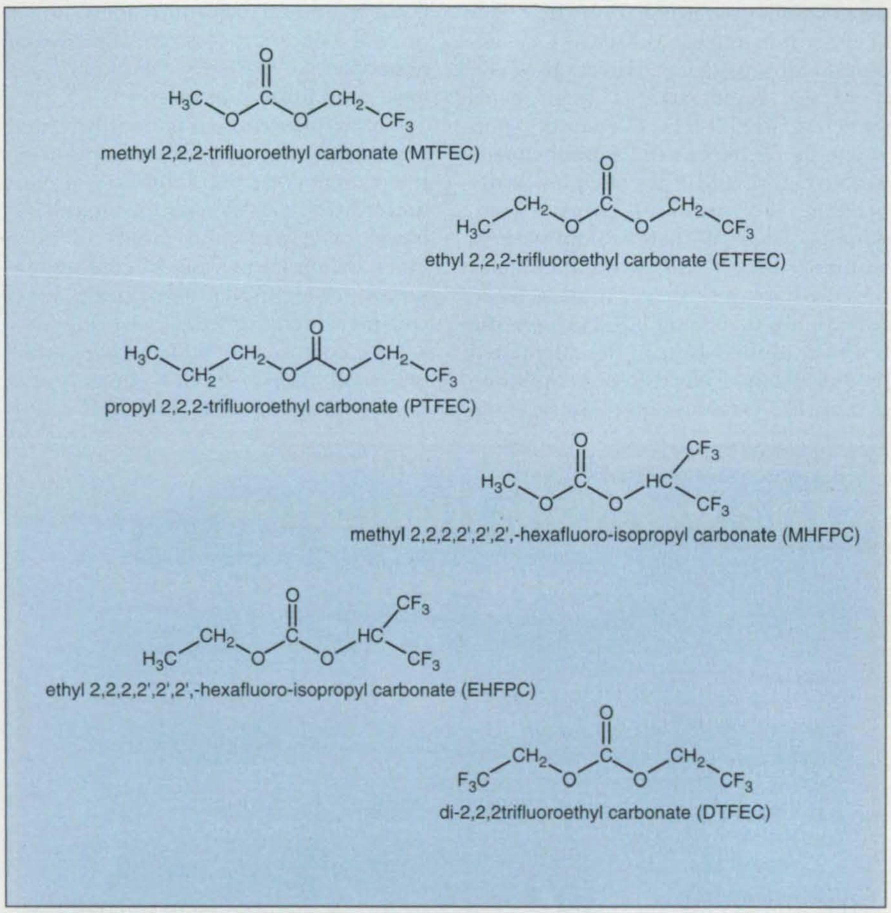
The partially fluorinated carbonate cosolvents and the electrolytes formulated by use of these solvents were evaluated in comparison with baseline (nonfluorinated) alkyl carbonate cosolvents and the corresponding baseline electrolyte formulation. The baseline mixture of cosolvents consists of equal volume parts of ethylene carbonate (EC), dimethyl carbonate (DMC), and diethyl carbonate (DEC). The baseline electrolyte formulation is a 1.0 molar solution of lithium hexaflurophosphate ($LiPF_6$) in the baseline mixture of cosolvents.

The partially fluorinated carbonate solvents studied (see figure) include:

- methyl 2,2,2-trifluoroethyl carbonate (MTFEC),
- ethyl 2,2,2-trifluoroethyl carbonate (ETFEC),
- propyl 2,2,2-trifluoroethyl carbonate (PTFEC),
- methyl 2,2,2,2′,2′,2′-hexafluoro-isopropyl carbonate (MHFPC),
- ethyl 2,2,2,2′,2′,2′-hexafluoro-isopropyl carbonate (EHFPC), and
- di-2,2,2-trifluoroethyl carbonate (DTFEC).

Ternary and quaternary mixtures containing various combinations of these cosolvents were used to formulate electrolytes containing $LiPF_6$ at concentrations of 0.5, 0.75, and 1.0 molar.

The fluorinated carbonate cosolvents exhibit the requisite chemical stability of the baseline cosolvents while offering



These **Partially Fluorinated Alkyl Carbonates** were tested as electrolyte cosolvents for rechargeable Li-ion cells.

more desirable physical properties imparted by the presence of the fluorine substituents. These more desirable properties include: (1) lower melting temperatures; (2) greater chemical and electrochemical stability; (3) lower intermolecular forces and lower polarizability, which result in lower surface energies; and (4) lower flammability and thus greater safety.

Laboratory test cells constructed with these electrolytes exhibited high capacities at temperatures from –20 °C to –40 °C, capability for high rates of charge and discharge at low temperatures, and low electrode polarization. Hence, these electrolytes appear to be useful for constructing rechargeable lithium-ion cells with high specific energies, long lifetimes, and ability to function well at low temperatures.

This work was done by Marshall Smart, Ratnakumar Bugga, Subbarao Surampudi, Surya Prakash, and Jinbo Hu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*

NPO-21076

Diaminobenzoquinones as Corrosion-Inhibiting Additives

Protection can extend beyond edges of paints to adjacent unpainted areas.

John F. Kennedy Space Center, Florida

Non-polymeric N,N′-di-N-hydrocarbyl-2,5-diamino-1,4-benzoquinones (where the hydrocarbyl substituents are alkyl or aryl) have been found to be useful as corrosion-inhibiting additives for paints and other conventional coating materials that are applied to steel and other metals. Prior coating additives made from reactions of benzoquinones with diamines are polymeric. Such polymers are expensive and difficult to make. Moreover, being polymers, they cannot diffuse much and hence are believed not to protect uncoated areas of metal against corrosion. In contrast, when used in proper concentrations, the present non-polymeric diaminobenzoquinones provide enhanced protection

that extends somewhat from the edges of coats into uncoated areas — an important advantage in situations in which there are imperfections (e.g., gaps, scratches, and blisters) in coats of paint.

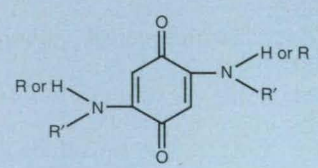
The figure depicts the generic molecular structure and lists examples of the present corrosion-inhibiting compounds. Each of these compounds is synthesized from 1,4-benzoquinone and the corresponding amine. In those listed compounds that contain NH groups, the reactivity of the NH groups is attenuated by the attached electron-poor quinone structures; consequently, those compounds are practically unreactive under normal conditions for curing coating materials, so that the compounds behave as additives, not reactives.

Unlike prior functionally substituted or polymeric diaminobenzoquinones, the present corrosion inhibitors are not limited to use in coating materials based on a particular family of polymers. Examples of types of coating materials to which the present compounds can be added for effective protection against corrosion include acrylics, polyesters, alkyds, polyamides, epoxies, phenolics, aminoplastics, polyimides, urethanes, silicones, and coating materials based on unsaturated drying oils.

The preferred amounts of these compounds lie in the range from 2 to 15 weight percent of coating solids. In each case, the chosen additive of this type is dissolved in the coating material (insofar as it is soluble) before the coating material is applied to steel. Alternatively or in addition, insofar as the additive is insoluble, it is dispersed into the coating material in finely powdered form. The standard paint-making techniques and materials can all be used in conjunction with the present corrosion-inhibiting compounds. In addition, the present corrosion-inhibiting compounds can be included in paints and other coating materials together with other corrosion-inhibiting compounds, such as chromates, molybdates, borates, and carbonates.

This work was done by Edward D. Weil of Polytechnic University for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-6373. Refer to KSC-11979.



EXAMPLES OF COMPOUNDS

2,5-di(methylamino)-1,4-benzoquinone
2,5-di(butylamino)-1,4-benzoquinone
2,5-di(dodecylamino)-1,4-benzoquinone
2,5-di(allylamino)-1,4-benzoquinone
2,5-di(cyclohexylamino)-1,4-benzoquinone
2,5-di(methoxyethylamino)-1,4-benzoquinone
2,5-diphenylamino-1,4-benzoquinone
2,5-di-*p*-tolylamino-1,4-benzoquinone
2,5-di(4-dodecylphenylamino)-1,4-benzoquinone
2,5-di(methoxyphenylamino)-1,4-benzoquinone
2,5-di(dodecylamino)-1,4-benzoquinone
2,5-di(dimethylamino)-1,4-benzoquinone
2,5-di(N-methyl-N-cocoylamino)-1,4-benzoquinone
2,5-dimorpholinyl-1,4-benzoquinone

In a **Generic Corrosion-Inhibiting Compound** of the present type, each of R and R′ is an alkyl, cycloalkyl, alkenyl, cycloalkenyl, or aryl group that is either unsubstituted or substituted with alkoxy or other non-polymer-reactive groups.

Loss-Tolerant Speech Codec

The design is based on the dynamics of speech, which can be learned off-line.

Lyndon B. Johnson Space Center, Houston, Texas

A coder/decoder system (codec) is being developed for use in a digital voice communication system in which speech is encoded as a series of frames of data and transmitted over a noisy or lossy channel. Called a "loss-tolerant speech codec" (LTSC), the system is designed to maintain the quality of reconstructed speech at the receiver (decoder) when frames are occasionally lost or corrupted by noise during propagation through the channel. Digital satellite and digital cellular telephone links are typical examples of channels in which frames can be lost or corrupted by noise. In addition, variable frame delays in packet-switching digital communication channels can occasionally become long enough to exert the same effect upon speech decoders as that of loss of speech during the affected frames.

The principal innovative aspect of this LTSC is a subsystem called an "intelligent speech filter" (ISF), which combines the latest neural-network technology with state-of-the-art speech-processing techniques. The ISF functions as a speech predictor or extrapolator; it reconstructs an approximate version of the missing speech frames on the basis of previous speech frames and of its knowledge of the dynamics of the vocal tract and pitch. The quality of speech reconstructed after transmission through a noisy channel is improved over that of other codecs because in a dynamical sense, the estimated speech inserted in the missing or erroneous frames sounds like the immediately preceding speech. In contrast, other codecs put out such distracting, discontinuous sounds as clicks, abrupt silences, or garbled speech in response to missing or erroneous frames.

The design of this LTSC will eventually call for high-speed microprocessors, parallel processing architecture, and efficient algorithm coding to implement its functions, which are shown in simplified form in the figure. The analog-to-digital converter in the transmitter linearly quantizes the input speech signal into a binary representation of 12 to 16 bits at a sampling rate of f_s. The digital input speech signal estimates the spectral envelope that represents the vocal tract, along with an appropriate driving function. Within the encoder, the digital input speech signal is first classified as either voiced or unvoiced, because the mathematical models for processing voiced and unvoiced signals are quite different; the model for voiced signals involves pitch-synchronous spectral analysis, while that for unvoiced signals involves linear prediction spectral analysis.

The decoder in the receiver includes the ISF plus signal-processing circuitry that determines whether or not each received frame of data is erroneous. If a frame is received without error, the data are decoded into a spectral envelope, frame energy, and pitch period for voiced speech. The decoded data are used to generate a speech time series, which is fed to a digital-to-analog converter for conversion to an analog output speech signal.

The decoded data are also sent to an input buffer in the ISF. When a frame of data is found to be lost or erroneous, the ISF uses the decoded data stored in the buffer during preceding frames to extrapolate the spectral envelope, energy, and pitch period into the missing or erroneous frame. The energy and pitch are both predicted by an all-pole infinite-impulse-response digital filter. The neural network is used to solve the most difficult part of the extrapolation problem, which is prediction of the spectral envelope.

The neural network is of a back-propagation-learning type. The neural network can be trained in the dynamics of speech by use of the time-varying spectral envelopes of representative samples of speech recorded from a variety of speakers. The neural network in the prototype ISF was trained on a single sentence from a single speaker, but the training set will eventually be expanded to include many sentences from many speakers, containing all phonemes and phoneme transitions.

This work was done by Jaime L. Prieto of LinCom Corp. for **Johnson Space Center.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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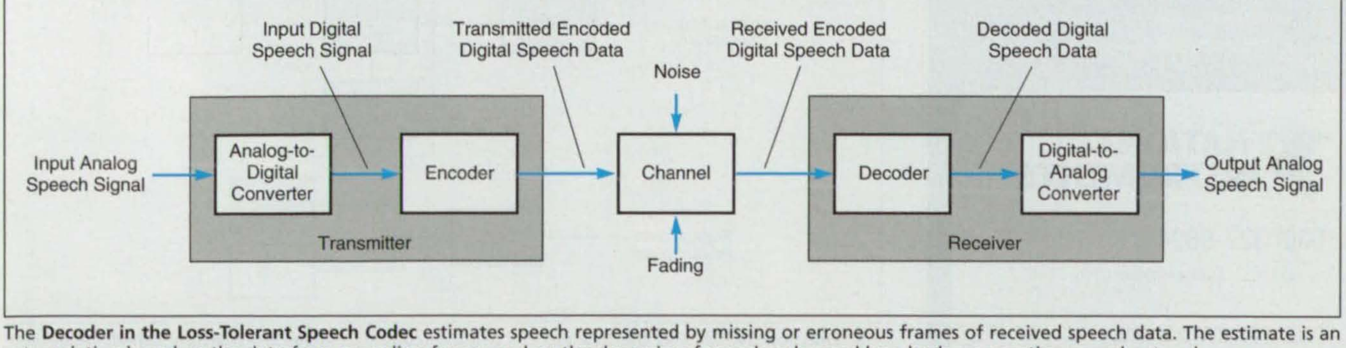

The **Decoder in the Loss-Tolerant Speech Codec** estimates speech represented by missing or erroneous frames of received speech data. The estimate is an extrapolation based on the data from preceding frames and on the dynamics of speech as learned by a back-propagation neural network.

Circuits Control Test Power-Turn-On and -Turn-Off Transients

Transients are repeatable and can be timed or phased precisely.

Marshall Space Flight Center, Alabama

Two electronic circuits that generate controlled power-turn-on and power-turn-off transients have been developed. These circuits are parts of a suite of test equipment used to measure the responses, to power-bus transients, of power supplies and power-consuming electronic circuitry aboard the space shuttle. These circuits can also be used in testing responses to power-bus transients in other closed electronic systems that include power sources and power-consuming equipment.

The figure is a simplified block diagram of the relationships among these circuits, a power source, and a piece of equipment under test (EUT). The power-distribution wiring between the power source and the EUT is modeled by a line impedance stabilization network (LISN), which is a circuit that contains lumped resistance(s), capacitance(s), and/or inductance(s). One of the circuits, called a "precision phase-controlled power switch" ("emission switch" for short), is designed specifically for turning on and/or turning off the power supplied to the EUT. The other circuit, called a "switching transient simulator" ("STS" for short), injects transients from a switched resistor-and-capacitor load into the connection between the LISN and the EUT to simulate the switching of power to circuits other than the EUT.

Prior to the development of the emission switch and the STS, turn-on and turn-off transients for testing were generated by use of mechanical switches. One disadvantage of mechanical switches is that they are susceptible to contact bounce and arcing, which give rise to nonreapeatability of switching waveforms. Another disadvantage of mechanical switches is that their opening and closing times cannot be controlled precisely; this is especially important in the case of an ac power supply, inasmuch as the open-switch voltage an infinitesimal time before turn-on or the closed-switch current an infinitesimal time before turn-off depends on the phase (that is, the time from the beginning of the power-supply cycle).

In the emission switch and the STS, the primary switching elements are field-effect transistors (FETs), which, unlike mechanical switches, are not susceptible to bounce or arcing. Moreover, FETs can be turned on or off starting at precise instants of time and with repeatable rise or fall times, by use of control signals with suitably timed and shaped waveforms. Both the emission switch and the STS can be synchronized with an ac power waveform so that they generate the required "on" or "off" transients at specified phases of the power cycle.

An additional notable feature of the emission switch is the inclusion of a timed mechanical relay switch. This switch is turned on 10 ms after the FET has been turned on and is turned off 10 ms before the FET is turned off. Thus, except for 10-ms intervals at the beginning and end of the "on" time, the mechanical switch bypasses the FET. This feature reduces the time-averaged power dissipated in the FET, thereby reducing the FET heat-sinking requirement.

This work was done by Ken Javor of EMC Compliance for **Marshall Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

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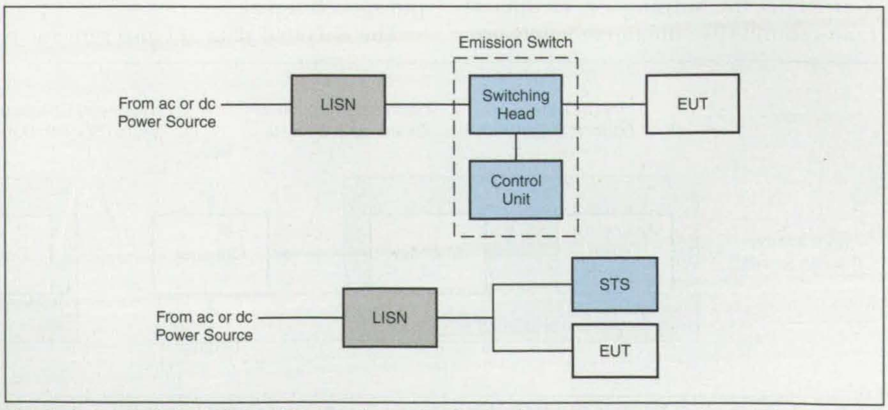

The **Emission Switch and the STS** are electronic circuits that generate precisely timed, repeatable switching transients for testing the EUT.

Multiple-Cavity Masers as 32-GHz LNAs

Advanced designs feature compactness and high performance.

NASA's Jet Propulsion Laboratory, Pasadena, California

Improved multiple-cavity ruby masers are under development for use as low-noise amplifiers (LNAs) for receiving very weak radio signals in frequency bands up to and including one centered approximately at 32 GHz. These masers were designed specifically to be incorporated into receivers in ground stations of NASA's Deep Space Network. The design may be useful in terrestrial cellular telephone terminals where high selectivity and immunity to the generation of intermodulation products may be needed.

The designs simplify field operations, afford high reliability, minimize required pump power levels, and provide noise temperatures near quantum limits. The low pump-power requirements enable operation in commercially available closed-cycle helium refrigerators at temperatures of ≤4 K. Another important aspect of the designs is small size, enabling the placement of many amplifiers in a single refrigerator in support of arrayed feeds, operation at multiple frequencies, and/or simultaneous dual-polarization operation, some or all of which are needed in many receiving systems.

A maser of this type includes a ruby-filled cavity, one or more signal-coupling cavities, one or more pump-coupling cavities, and a pump-reject filter, all combined in a single amplifier assembly. Signals are routed to and from the amplifier assembly via a transmission line (which is a waveguide in the case of 32 GHz) connected to a circulator. At 32 GHz, the amplifiers are small enough that twelve of them can fit within a single solenoid that has an inner diameter of 10 cm.

Each amplifying cavity is a half-wave-length waveguide resonator filled with ruby (having dimensions of 2.601 by 1.3005 by 1.016 mm in the 32-GHz case). The pump-reject filter is located in a waveguide, called the "signal waveguide," between the ruby and the circulator. This filter reflects the pump energy that has passed through the ruby back to the ruby, thereby confining the pump energy to the amplifier in order to maximize the pumping efficiency.

The tuning range of the 32-GHz version covers the deep-space-to-Earth frequency allocation of 31.8 GHz to 32.3 GHz with an instantaneous bandwidth of at least 100 MHz and an amplifier noise temperature of 3.1 K. Slightly lower noise temperature may be possible when this maser is operated in a refrigerator at a physical temperature <2.2 K.

This work was done by James Shell and Robert Clauss of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

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May 2002

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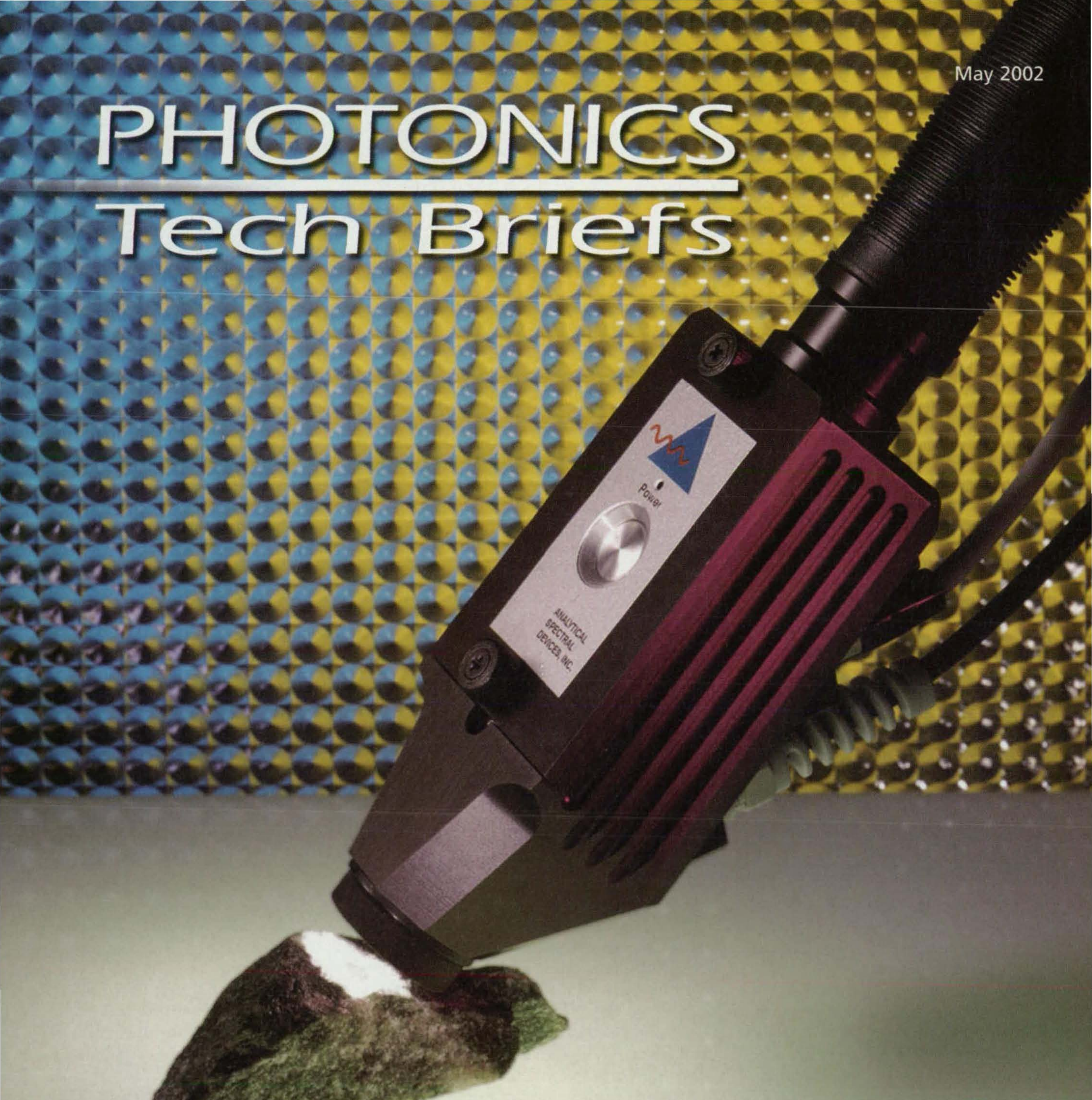

Cover photo courtesy of Analytical Spectral Devices, see page 13a

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3D MEMS for Optical Cross-Connect Switches: A New Means of Managing Network Traffic

In the past several years the growth of optical networks and the amount of data being transmitted through them has generated great interest in new means of managing network traffic. One of the most promising is the optical cross-connect (OXC), which is designed to enable the switching of light signals from a group of input fibers to a group of output fibers with no transition to electrical signals in between, as is the current standard.

It is believed that avoiding the transitions to and from electrical signals will offer a number of advantages. This all-optical method is bit-rate and protocol transparent, which means the OXC is able to function even as the bit-rate grows and as the data transmission protocol changes. In addition, direct optical switching is highly scalable and provides telecommunication carriers with a value proposition that avoids the expensive high-speed electronics used in current optical-electrical-optical (OEO) topologies.

There are a number of technologies that provide for direct optical switching including liquid crystals, bubbles, holograms, and microelectromechanical systems (MEMS). Of these approaches, MEMS is widely believed to be the most promising for large-scale optical cross-connects.

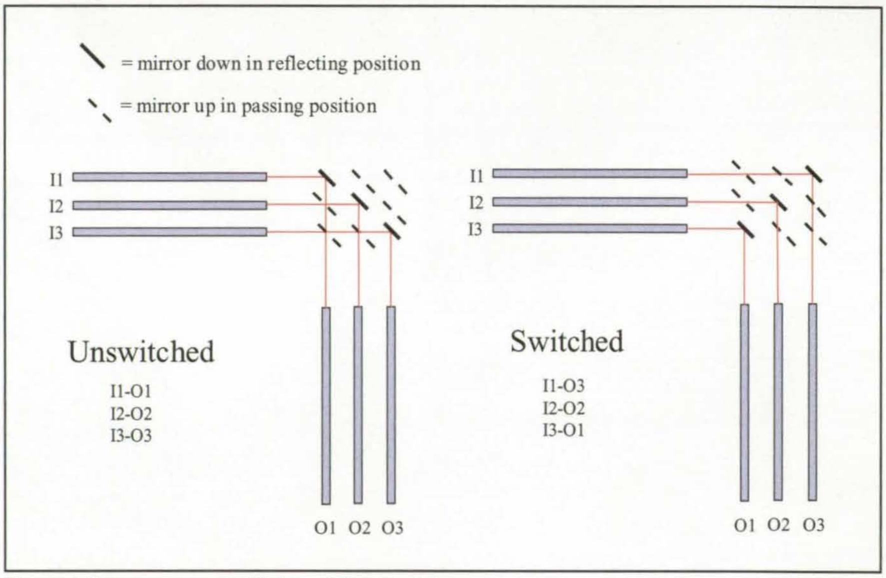

Figure 1: 2D cross-connect in two different states.

MEMS for Optical Cross-Connect Switches

The two major approaches for MEMS OXCs are the so-called 2-D and 3-D approaches. The 2-D approach involves arranging a set of MEMS mirrors in a plane. Each mirror is placed at a fixed angle with respect to the incoming light and is moved in and out of the path of the light like a shutter. By cascading sets of these mirrors one is able to steer the input from M input fibers to N output fibers. For the case in which M=N, the total number of mirrors required is equal to N^2. The so-called non-blocking Clos architecture can reduce the number of mirrors but adds a large amount of complexity to the system. A diagram of a simple 3×3 switch is shown in Figure 1 with a total of 3^2=9 mirrors. Two different states are shown. In the first state, each input fiber is connected to its companion output fiber. In the second state, the outputs of fibers 1 and 3 are switched. This approach works quite well for small port counts (N<32) but as the port number grows, the system requires many more mirrors and the total path length increases, which increases the insertion loss.

At these higher port counts, 3D MEMS technology is the preferred choice. 3D MEMS arrays operate by steering beams of light in an analog fashion in 3-dimensional space. For N fibers in and N fibers out the total number of mirrors needed is 2N and the length that the light travels does not increase as quickly with port count as it does for 2D configurations.

The general configuration for such an array is represented in the schematic of Figure 2, which shows an arrangement with 3 mirrors on each array. The diagram shows a standard arrangement of the arrays with respect to the fibers and how the mirrors rotate to switch the output fiber to which each input fiber is connected. Each mirror can rotate about 2 axes and can direct incident light to any mirror in the companion array. The mirror in this array then redirects the light so that it enters the correct output fiber at normal incidence. The fundamental functionality required of each mirror thus is the ability to rotate to many different positions in both the x and y-axes and hold that position for extended periods of time (up to years) with high accuracy. The fact that the mirror is functioning in an analog fashion greatly increases the complexity of the system.

The mirrors for these arrays typically consist of silicon plates coated with a film that has a high reflectivity at the wavelengths used in the network. Each mirror is suspended in space by springs that are compliant enough to allow the mirror to rotate in response to forces applied to it. Because the mirror must be able to rotate about two axes, it is often suspended within a gimbal, which is itself suspended from a fixed structure as shown in Figure 3. This structure allows the mirror to rotate about one axis

within the gimbal, which in turn can rotate about the perpendicular axis. In this way the mirror can achieve compound angles of rotation.

The means by which the actuation of the mirror is achieved can be of many forms but often falls into one of two categories: electrostatic and electromagnetic.

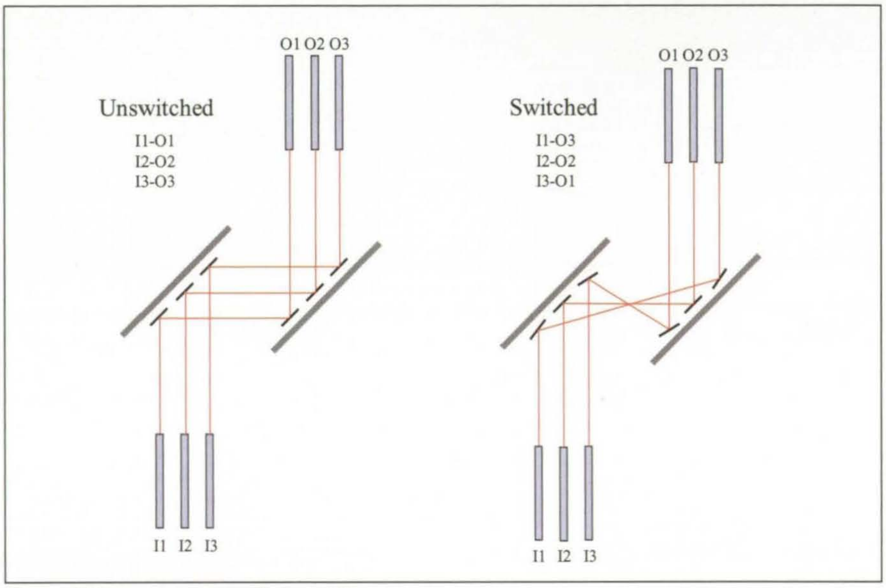

Figure 2: 3D cross-connect in two different states.

Electrostatic Actuation

Electrostatic actuation consists of applying a bias between two conductors, which induces an attractive force between them. Whether achieved through a parallel plate or comb-drive architecture, this actuation scheme is very commonly used and has a number of advantages including low power consumption and relative ease of design. The parallel plate architecture is more straightforward and easy to fabricate but suffers from high-voltage requirements and strong non-linearity of force versus displacement. The comb-drive architecture is more linear and requires smaller voltages, but it is significantly more difficult to fabricate.

Electromagnetic Actuation

The other main actuation type is electromagnetic, which uses the interaction between an electromagnet and a permanent magnet to rotate the mirror. These devices have the advantages of relatively large torques when used with larger mirrors, and a smaller number of leads per mirror. They do, however, consume more power, which can lead to challenges of heat dissipation. They can also be more complicated to package, as they typically will involve the assembly of external magnets or coils.

Critical Figures of Merit for 3D MEMS:

There are many requirements imposed on the 3D MEMS that form the core of an OXC. Some of the most important of these are:

Maximum angle- the most basic requirement for each mirror in an array is that it can rotate enough to direct light to any mirror in the opposing array.

Mirror size/fill factor- the size of the mirrors in an array must be large enough to capture a large percentage of the incoming light and is thus heavily dependent on the optical design of the system. For a given mirror size, it is often desired to have a high "fill factor" which is the area of each mirror divided by the area of each pixel.

ROC (Radius of Curvature)- in order for the mirrors to be sufficiently reflective, they are coated with a film, which is typically gold. This film will induce some curvature on the mirror, which can be quantified by its radius of curvature. The curvature can induce an unwanted spreading of the reflected light. Therefore, it is necessary to keep this curvature low, i.e. keep the ROC high.

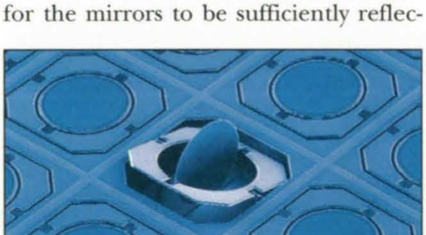

Figure 3: SEM micrograph of micromirror array.

Switching speed- to fit into the protocol of many optical fabrics, the switching speed often must be less than 10 ms to ensure uninterrupted service. To achieve such switching speed, MEMS designers reduce the mass of the rotating structures while increasing the maximum torque applied to them.

Pointing stability- as the mirror drifts from its ideal angle, the light it deflects is steered away from the center of the fiber to which it is directed causing a decrease in signal strength. The extent to which angular error manifests itself in an increase in insertion loss is critically dependent on the optical design of the system. This requirement can be quite challenging under shock, vibration, and temperature cycling and is one of the main drivers for closed loop control.

Scalability- one of the advantages of 3D MEMS is its ability to scale to higher port counts without any radical change in its implementation. However, a number of challenges do arise at higher port counts ranging from increased angular deflection and pointing stability requirements to the difficulty of routing an increasing number of leads.

Reliability- this area is very broad and is influenced by almost every aspect of system design. Reliability tests are governed by the conventional Telcordia specifications. These are used to qualify a system to ensure that it meets standard telecommunication reliability requirements. MEMS designers have the challenging task of meeting these explicit requirements and any additional ones proposed by a specific customer. This often involves a careful choice of materials whose properties change little over time, the use of small actuation signals (whether voltage or current), and hermetic packaging of the device to minimize environmental effects.

Summary

MEMS offer many advantages as a technology platform for optical switching and specifically as the core of a large port count OXC. As with any emerging technology, the 3D MEMS OXC will ultimately succeed or fail based on its ability to meet customer demands for functionality and price. The success in meeting these requirements will have a great impact on the field of optical networking as well as on the future of MEMS itself.

Dr. Thomas Kudrle is the Lead Engineer of MEMS OXC at Corning IntelliSense Corporation. For more information contact Dr. Kudrle at KudrleTD@corning.com or by telephone at (978) 988-8000, ext. 2311. Visit IntelliSense at www.intellisense.com or contact the main office at IntelliSense Corporation, 36 Jonspin Road, Wilmington, MA, 01887, USA.

Product Guide: Continuous-Wave Diode Lasers

Diode lasers, also known as laser diodes or semiconductor lasers, are small rugged devices that require low levels of power. These characteristics enable them to operate in environments and spaces where other lasers cannot function. Other characteristics include long life expectancy and sensitivity to electrostatic shock. Low cost, high volume manufacturing using standard semiconductor fabrication techniques has also helped to fuel the prevalent use of diode lasers in communications, illumination, materials processing and medical applications, for example.

This month the product guide focuses on continuous-wave (CW) diode lasers. Continuous-wave lasers generate an uninterrupted, coherent beam of light. Beam coherency is critical for a variety of applications including communications. CW lasers generally produce lower output power than pulsed lasers, which at fixed intervals generate a momentary amplification of coherent light followed by a return to the previous state.

Due to the large number and diverse types of diode laser offerings, those featured in the table are only representative of available products. A majority of companies offer custom diode lasers along with standard offerings. Product entries are arranged by wavelength. All figures in the table are typical unless otherwise noted. Manufacturer web addresses are provided in a separate table. The manufacturer should be contacted directly for additional information.

Wavelength (nm)	Output Power	Operating Current	Spectral Width (nm)	Beam Divergence (degrees)	Features	Company	Model No.
635	1mW	70mA	4	6.3	Fiber pigtailed	Newport	LD-635-31A
635 to 680	10mW	60mA	—	8x35	C-mount, 5.6mm, & 9mm	SLI Corp.	SLI-CW-XXX-C1-XXX-0.01S-R
650 to 695	100mW	600mA	—	8x37	Window packages	Applied Optronics	AOCI-100-T3
650 to 665	150mW	700mA	—	—	Fiber packages	Applied Optronics	AOCI-150-HHL100
666 to 695	60mW	600mA	—	—	Fiber packages	Applied Optronics	AOCI-60-HHL100
666 to 695	125mW	650mA	—	—	Fiber packages	Applied Optronics	AOCI-125-HHL100
666 to 695	400mW	900mA	—	8x37	Window packages	Applied Optronics	AOCI-400-T3 & HHL
670	0.3mW	45mA	—	—	Fiber pigtailed	Newport	LD-670-11A
670	1.2mW	60mA	—	12.7	Fiber pigtailed	Newport	LD-670-21B
670	500mW	900mA	1	40x10	C, TO3, 9mm, & HHL packages	High Power Devices	HPD-1305
675	3W	8A	<6	<0.16 NA	Fiber array	Coherent, Inc.	FAP-67-3000C-800-B
690	4W	9A	<6	<0.16 NA	Fiber array	Coherent, Inc.	FAP-69-4000C-800-B
730 to 750	250mW	900mA	—	8x38	Window packages	Applied Optronics	AOCI-250-T3 & HHL
780 to 1060	500mW	500mA	—	8x40	C-mount, 9mm, & fiber coupled	SLI Corp.	SLI-CW-XXX-C1-XXX-0.5M-R
780 to 980	500mW	750mA	2	40x10	C, TO3, & 9mm packages	High Power Devices	HPD-1005
780 to 995	500mW	950mA	—	9x43	Window packages	Applied Optronics	AOCI-500-T3 & HHL
780 to 1060	1W	1A	—	8x40	C-mount, 9mm, & fiber coupled	SLI Corp.	SLI-CW-XXX-C1-XXX-1M-R
780 to 980	1W	1.3A	2	40x10	C, TO3, 9mm, & HHL packages	High Power Devices	HPD-1010
780 to 995	1W	1.4A	—	9x43	Window packages	Applied Optronics	AOCI-1000-T3 & HHL
780 to 1060	2W	2A	—	8x40	C-mount, HPC, & TO3	SLI Corp.	SLI-CW-XXX-C1-XXX-2M-R
780 to 940	2W	2.5A	2	40x10	C, TO3, & HHL Packages	High Power Devices	HPD-1620
780 to 1060	5W	5.8A	—	8x40	HPC & LD packages	SLI Corp.	SLI-CW-XXX-C1-XXX-5M-R
780 to 980	5W	6.5A	2	40x10	HHL package	High Power Devices	HPD-1050
780 to 1060	15W	16A	—	8x40	SLD, LD, & LT packages; bars	SLI Corp.	SLI-CW-XXX-B1-XXX-15M-R
780 to 840	16W	32A	<4	<0.16 NA	Fiber array	Coherent, Inc.	FAP-λ-16C-800-B
780 to 1060	30W	16A	—	.22NA	Fiber coupled	SLI Corp.	SLI-CW-FCLD-B4-XXX-30M-F
780 to 840	30W	45A	<5	<0.16 NA	Fiber array	Coherent, Inc.	FAP-λ-30C-800-BL
780 to 840	60W	45A	<5	<0.16 NA	Fiber array	Coherent, Inc.	FAP-λ-60C-1200-BL
780 to 1060	60W	60A	—	8x40	Water-cooled LT & bars	SLI Corp.	SLI-CW-XXX-B1-XXX-60M-R
785	3mW	100mA	—	—	Fiber pigtailed	Newport	LD-785-51B
785	6mW	55mA	—	12.7	Fiber pigtailed	Newport	LD-785-61C
798 to 800	2W max.	2.5A	2	12x32	A & P1 packages	JDS Uniphase	SDL-2460 Series
798 to 800	4W max.	6.3A	2	12x32	C & P1 packages	JDS Uniphase	SDL-2380 Series
808	500mW	150mA	2.5	12x40	Fiber pigtailed, C & 9mm	Laser Diode, Inc.	CW 0500 Series

Wavelength (nm)	Output Power	Operating Current	Spectral Width (nm)	Beam Divergence (degrees)	Features	Company	Model No.
808	500mW	800 mA to 1.2A	—	10x40	C, HHL, & TO3 packages	Newport	LD-808-500C
808 to 810	500mW max.	800mA	2	12x32	C, H1, & P1 packages	JDS Uniphase	SDL-2350 Series
808	1W	300mA	2.5	12x40	Fiber pigtailed, C & 9mm	Laser Diode, Inc.	CW 1000 Series
808	1W	1.1 to 1.5A	—	10x40	C, HHL, & TO3 packages	Newport	LD-808-1000C
808	1W	1.25A	<5	<36x<10	Open heatsink, single emitter	Spectra-Physics	SCT100-808-Z1-01
808	2W	600mA	2.5	12x40	Fiber pigtailed, C & 9mm	Laser Diode, Inc.	CW 2000 Series
808	2W	2.4 to 3.2A	—	10x40	C, HHL, & TO5 packages	Newport	LD-808-2000C
808	5W	1.3A	2.5	12x40	Fiber pigtailed, C & 9mm	Laser Diode, Inc.	CW 5000 Series
808	15W	21 to 28A	—	10x40	1 cm bar	Newport	LD-808-15C-30-A
808	15W	≤30A	<4	0.11NA	Fiber coupled	Spectra-Physics	BFx0825-808-15-01
808	15W	32A	<6	0.22 NA	0.6mm fiber coupled	Apollo Instruments	F15-808-6
808	16W	6.5A (series)	3	10	Fiber coupled array	High Power Devices	HPD-1916-FCA
808	20W	27 to 30A	—	10x40	1 cm bar	Newport	LD-808-20C-30-A
808	20W	28A	3	40x10	Laser bar	High Power Devices	HPD-1220
808	25W	52A	<6	0.22 NA	0.6mm fiber coupled	Apollo Instruments	F25-808-6
808 to 980	30W	42A	—	.22NA	Water-cooled fiber coupled	SLI Corp.	SLI-CW-WFCLD-B1-XXX-30M-F
808	30W	≤60A	<4	0.11NA	Fiber coupled	Spectra-Physics	BFx0825-808-30-01
810, 830, 852	50mW max.	95 mA	3	9x30	C, G1, & H1 packages	JDS Uniphase	SDL-5400 Series
810, 830, 852	150mW max.	210 mA	3	9x30	C, G1, & H1 packages	JDS Uniphase	SDL-5420 Series
810	1W	1.8 to 2A	—	—	HHL package	Newport	LD-810-HHL200
810	2W	2.1A	—	9x43	HHL package	Applied Optronics	AOCI-1600-HHL
815 to 845	1W max.	1.7A	3	14	Fiber coupled	JDS Uniphase	JDSUniphase-2364-L2
830	200mW max.	270 mA	3	9x30	C, G1, & H1 packages	JDS Uniphase	SDL-5430 Series
830	1W	1.25A	<5	<36x<10	Open heatsink, single emitter	Spectra-Physics	SCT060-830-Z1-01
830	15W	≤30A	<4	0.11NA	Fiber coupled	Spectra-Physics	BFx0825-830-15-01
910 to 930	4W max.	4.8A	5 max.	12x28	A-block package	JDS Uniphase	SDL-6380-A
915	1W	1.25A	<5	<36x<10	Open heatsink, single emitter	Spectra-Physics	SCT100-915-Z1-01
915	30W	≤60A	<4	0.11NA	Fiber coupled	Spectra-Physics	BFx1160-915-30-01
930 to 950	16W	27A	<4	<0.16 NA	Fiber array	Coherent, Inc.	FAP-940-16C-800-B
940	1W	1.25A	<5	<36x<10	Open heatsink, single emitter	Spectra-Physics	SCT100-940-Z1-01
940	1.4W	1.55A	—	9x43	Window packages	Applied Optronics	AOCI-1400-HHL
940	30W	45A	<5	<0.16 NA	Fiber array	Coherent, Inc.	FAP-λ-30C-800-BL
960 to 980	2W max.	2.6A	6 max.	14x35	A-block package	JDS Uniphase	SDL-6370-A
975	1W	1.25A	<5	<36x<10	Open heatsink, single emitter	Spectra-Physics	SCT100-975-Z1-01
975	15W	≤30A	<4	0.11NA	Fiber coupled	Spectra-Physics	BFx0825-975-15-01
975	15W	28A	<4	<0.18 NA	Fiber array	Coherent, Inc.	FAP-λ-15C-800-B
980	>1mW	<30 mA	2-3	—	Fiber pigtailed	B&W Tek, Inc.	BWKM-980
980	1W	1.3 to 1.6A	—	10x35	C, HHL, & TO3 packages	Newport	LD-980-1000C
980	2W	2.1A	—	9x43	HHL package	Applied Optronics	AOCI-1600-HHL
980	2W	2.4 to 3A	—	10x35	C & HHL packages	Newport	LD-980-2000C
980	22W	40A	<4	<0.18 NA	Fiber array	Coherent, Inc.	FAP-λ-22C-800-B

Company	URL
Apollo Instruments	www.apolloinstruments.com
Applied Optronics Corp.	www.appliedoptronicscorp.com
B&W Tek, Inc.	www.bwtek.com
Coherent, Inc.	www.coherentinc.com
High Power Devices, Inc.	www.hpdinc.com
JDS Uniphase	www.jdsu.com
Laser Diode, Inc.	www.laserdiode.com
Newport	www.newport.com
Semiconductor Laser International (SLI) Corp.	www.slicorp.com
Spectra-Physics, Semiconductor Lasers	www.spectra-physics.com

Technologies of the Month

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Efficient Heat Exchanger With Compact Size

This high efficiency heat exchanger has a small overall size that makes economical production possible. The device has many applications but is particularly suitable for heating and cooling machines operating by a regenerative gas cycle process.

This heat exchanger is characterized by the separation of the media taking part in the heat transfer. Running a groove (or multiple grooves) from the inlet to the outlet on one surface of the heat exchanger's base body enables high-efficiency despite the compact size. A cover seals the groove to form a flow channel for the heat-absorbing heat transfer medium. The other surface of the base body has a multitude of channels and/or pores for the heat-emitting medium. There are a variety of ways to configure these channels and/or pores.

For more information go to:
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Sealing Method for Reducing Semiconductor Package Defects

Semiconductor packages are hermetically sealed to protect semiconductor device chips from mechanical damage and contamination such as dust, chemicals, gases, and humidity. Typically a semiconductor device chip is sealed in a rectangular package by applying adhesive (usually a sealing solder) to the plating layer of the package body and then pressing the lid against the package body while the entire structure is heated. Inert gas is also sealed in the package to help protect the chips. This method of adhering a lid with an adhesive while being heated under pressure can leave voids in the hermetic seal portion - the overlapping portion between the lid and the plating layer of the package body. The inert gas sealed inside can then leak through causing sealing defects.

This proposed method of sealing a semiconductor package intends to reduce defects in the seal portion of a semiconductor device, improve the adhesion strength of the seal, and increase the uniformity of the eutectic reaction. The proposed method uses semiconductor device packages consisting of a semiconductor device chip mounted on the package body and a lid that is adhered to the an annular plating layer formed by applying an adhesive to the package body. The package body and/or lid are then pivoted about an axis coaxial with the adhesion layer before the adhesive hardens. A sealing device is used to pivot the package and or lid as described above. The apparatus consists of a table for supporting the package body; a lid holding jig; means for vertically moving the table and/or the lid holding jig; and means for rotating the table and/or lid holding jig. The scrubbing enabled by this apparatus breaks the surface oxide film formed on the preform.

For more information go to:
www.nasatech.com/techsearch/tow/scrubbing.html
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Wire Cutters for High-Precision Cutting Applications

This technology addresses the disadvantages of conventional fixed-abrasive wire tools resulting in a longer service life, improved cutting precision and efficiency, and lower costs. With their flexibility and small diameter, the diamond wire cutters can be used in a variety of high-precision cutting applications.

The manufacturing process for this wire tool utilizes light-curing resin as the bonding material. When irradiated by ultraviolet or visible lights, the resin polymerizes and hardens within a few seconds through photoreaction. This allows the wire tools to be produced at a rate of hundreds to thousands of meters per minute. Metal particles or inorganic powders with a mean grain diameter of 0.1 to 15 micrometers are also added to the resin in order to improve the mechanical strength and heat resistance of the tools.

For more information go to:
www.nasatech.com/techsearch/tow/cutter.html
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Arrays of QWIPs With Spatial Separation of Multiple Colors

Spectral imagers could be made simpler, smaller, lighter, and less costly.

NASA's Jet Propulsion Laboratory, Pasadena, California

Focal-plane arrays of quantum-well infrared photodetectors (QWIPs) featuring adjacent pixels sensitive to different colors have been proposed. An array of this type would make it possible to image the same scene in multiple wavelength bands simultaneously on the same focal plane, without need for moving parts or for complex optics to split light into wavelength bands and make the light in each band impinge on a separate detector array optimized for that band. Hence, these arrays would make it possible to develop a new generation of spectral imagers that would be smaller, lighter, and less costly, relative to spectral imagers now or previously in use.

The figure is a schematic cross section of one pixel of a four-color array according to the proposal. The pixel would be divided into four adjacent sub-pixels, each sub-pixel optimized for one of the four desired wavelength bands. All the sub-pixels would contain identical stacks of four multiple-quantum-well (MQW) photodetectors (for all four bands), but as described below, functional electrical connections would be made to only the one MQW photodetector that was optimized for the wavelength band assigned to a given sub-pixel.

Each MQW photodetector in a stack would comprise 30 spatial periods of layers of GaAs quantum wells separated by $Al_xGa_{1-x}As$ barriers; the parameters of the layers would be chosen to maximize sensitivity in the designated wavelength bands. The photodetectors for the different wavelength bands would be separated by intermediate contact layers.

Fabrication of the array would begin with the growth of a wafer comprising all of the MQW, contact, and ancillary GaAs and $Al_xGa_{1-x}As$ semiconductor layers. Next, the pixels and sub-pixels would be defined by photolithographic processing, including masking, etching, chemical vapor deposition, and deposition of metal. The wavelength band for each sub-pixel stack would be delineated by use of a deep groove etch to make contact with the intermediate contact layers of the MQW photodetector for that band while short-circuiting the contact layers of the MQW photodetectors for the other bands. Short-circuiting would be effected by forming grids of gold-coated, reflective etched lines. In addition to serving as shorting conductors, these grids would constitute two-dimensional diffraction gratings that would be optimized for coupling light into the MQWs. For multicolor QWIPs, the grating grooves also serve to deactivate redundant quantum-well stacks (see figure). To ensure sufficient groove depth to penetrate inactive quantum-well stacks, as well as to provide light coupling, three-quarter or five-quarter wavelength groove depths have been used. [The need for such light couplers and the use of two-dimensional diffraction gratings to satisfy this need was described in "Cross-Grating Coupling for Focal-Plane Arrays of QWIPs" (NPO-19657) *NASA Tech Briefs*, Vol. 22, No. 1 (January 1998), page 6a.]

This work was done by Sumith Bandara, Sarath Gunapala, John K. Liu, David Ting, Sir B. Rafol, and Jason Mumolo of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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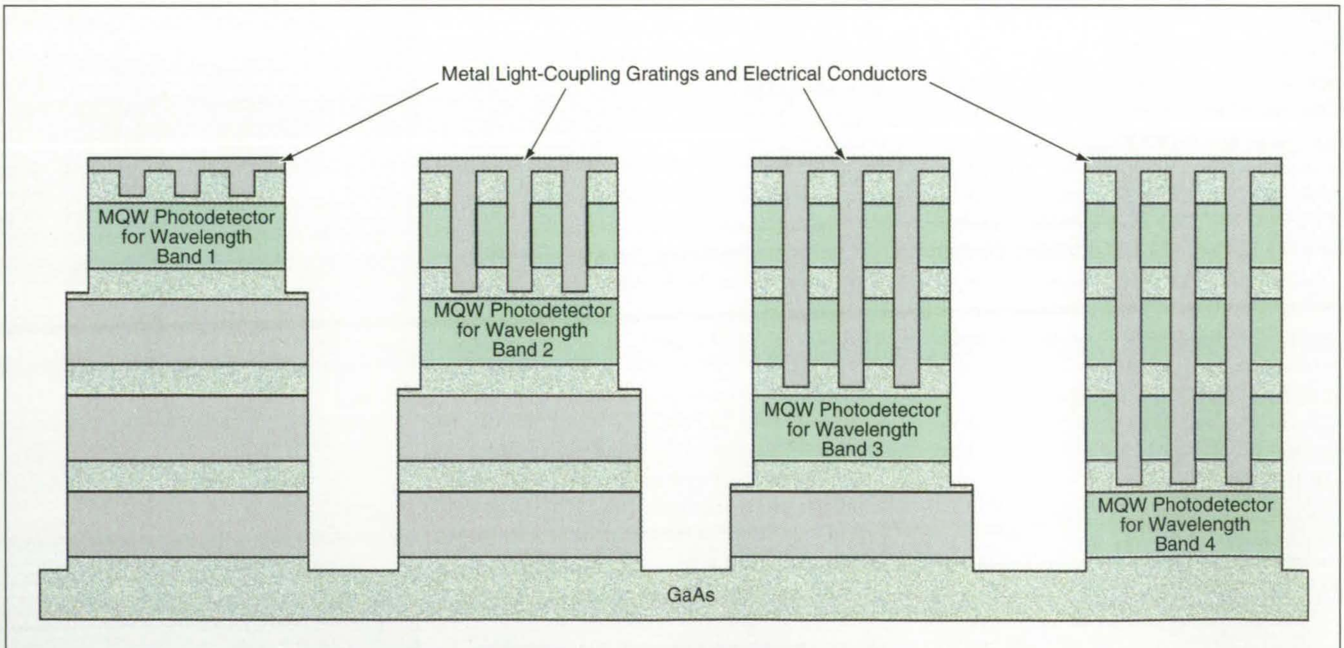
Refer to NPO-21084, volume and number of this NASA Tech Briefs *issue, and the page number.*



Sub-Pixel Stacks would contain identical semiconductor layers. They would differ in their light-coupling two-dimensional diffraction gratings and electrical contacts.

Two-Fiber-Optic Method of Laser Doppler Velocimetry

Only one laser, instead of two, is needed.

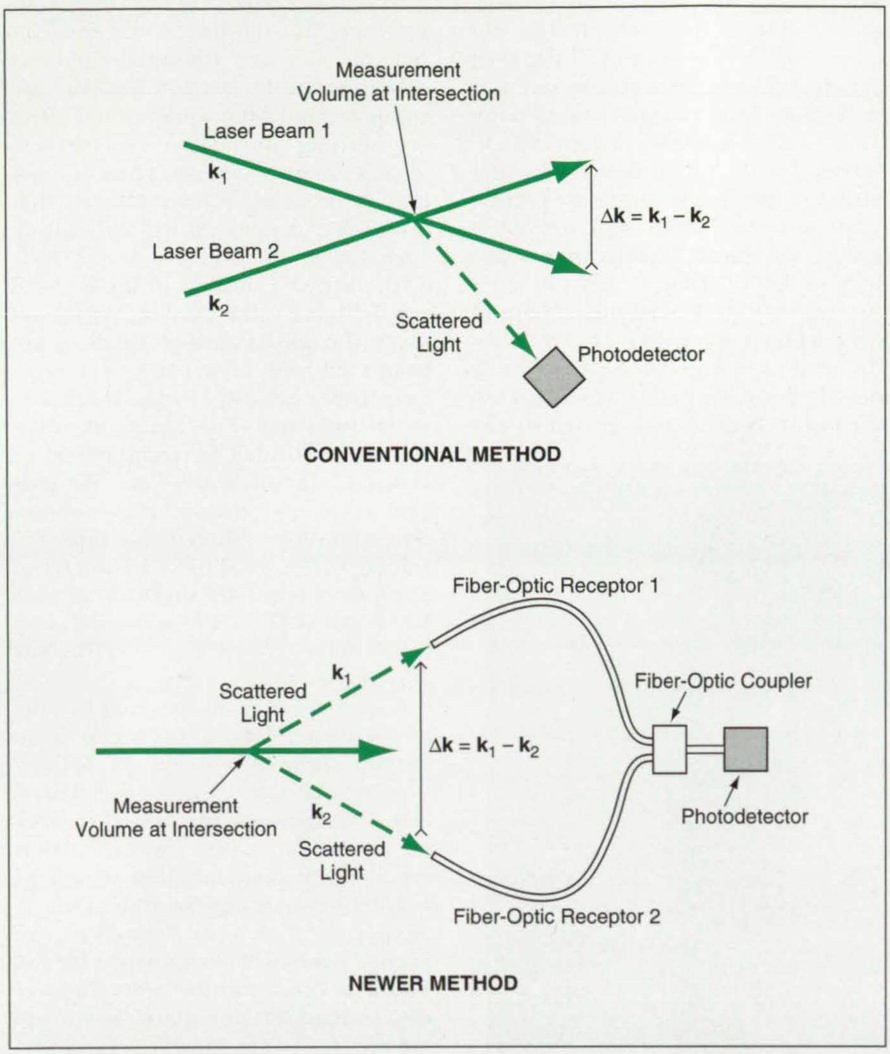
John H. Glenn Research Center, Cleveland, Ohio

The figure depicts the basic optical layouts for (1) conventional laser Doppler velocimetry (LDV) and (2) a newer method of LDV based partly on the use of two optical fibers. Whereas conventional LDV involves the use of at least two lasers aimed in specified direction and detection of light scattered to one detector in almost any direction, the newer method involves only one laser and fiber-optic receptors that collected light scattered in two specified directions.

In conventional LDV, two coherent laser beams are made to intersect in a small measurement volume, where they interfere. As a seed particle entrained in a flow passes through the measurement volume, the laser light reflected by the particle is modulated at a frequency proportional to the spatial frequency of the interference fringes and the component of velocity perpendicular to the interference fringes. More specifically, the modulation frequency is given by $\Delta f = (1/2\pi)\boldsymbol{v}\cdot\Delta\boldsymbol{k}$, where $\boldsymbol{v}$ is the velocity and $\Delta\boldsymbol{k} = \boldsymbol{k}_1 - \boldsymbol{k}_2$ is the difference between the wave vectors of the two laser beams. Because Δf is independent of the direction in which the light is scattered, a photodetector can be placed in any convenient position to receive the scattered light. The output of the photodetector is processed to extract Δf and thus the component of $\boldsymbol{v}$ in the $\boldsymbol{k}_1 - \boldsymbol{k}_2$ direction.

In the newer method, the measurement volume lies in a small region somewhere along a single illuminating laser beam, but in this case, the measurement volume lies at (and is defined by) the intersection of the laser beam and the lines of sight of two fiber-optic receptors. To obtain a high signal-to-noise ratio, these receptors are constructed in the form of polarization-preserving, single-mode optical fibers. Scattered light collected by these receptors is combined in a fiber-optic coupler and delivered to a photodetector, where interference between the beams scattered in the two directions gives rise to a Doppler beat frequency. This beat frequency is given by the same equation as that for the modulation frequency in conventional LDV, except that in this case, $\Delta\boldsymbol{k} = \boldsymbol{k}_1 - \boldsymbol{k}_2$ is the difference between the wave vectors (at the laser wavelength) defined by the lines of sight from the measurement volume to the input ends of the two fiber-optic receptors. In this case, Δf is independent of the direction of the laser beam; hence, it is possible to illuminate the measurement volume from any convenient direction. The beat frequency can be measured by use of a standard LDV signal processor, a commercial digital photon correlator, or a fast digital correlator.

Unlike in conventional LDV, it is not necessary to add more lasers operating at different wavelengths and aimed in different directions in order to be able to measure additional velocity components. Instead, it suffices to add pairs of fiber-optic receptors aimed to define



The **Conventional Method and the Newer Method** of LDV differ in, among other things, the manner of producing interference. In conventional LDV, the interference occurs between two laser beams in the small measurement volume. In the newer method, the interference takes place in the fiber-optic coupler and photodetector.

the corresponding orthogonal wave-vector differences, plus the signal-processing equipment needed to extract the beat-frequency outputs of the additional receptors.

This work was done by Penger Tong, Bruce J. Ackerson, and Walter I. Goldburg of Oklahoma State University for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17136.

Stabilization and Registration of Sequential Video Images

Images are corrected for translation, rotation, and dilation.

Marshall Space Flight Center, Alabama

A computational process converts a sequence of digitized video images of the same scene into stabilized, coregistered images of an area of interest within the scene. The process corrects for motion of the area of interest or of the camera (as manifested by rotation, translation, and/or dilation of the raw images). Thus, there is minimal translation, rotation, or dilation in the se-

quence of output images of the area of interest. The stabilization and coregistration of images can facilitate scientific, engineering, or forensic analysis of the area of interest. Alternatively or in addition, the output images can be used to synthesize a single video image with reduced noise.

Older processes that were developed to serve the same purpose correct for translation but not for rotation or dilation. They are sensitive to effects of parallax (as manifested in differences between velocities of foreground and background objects). Most of them are not capable of resolving image displacements to resolutions finer than one pixel. The present process not only corrects for both rotation and dilation but is also less sensitive to parallax and can resolve motion and achieve registration to within a fraction of a pixel.

The process begins with the selection of an initial or reference video field — the key field — that includes the area of interest. The other fields in the sequence are known as test fields. The area of interest in the key field is identified and extracted for comparison with a corresponding area of the same size in each test field. Cross-correlations between the area-of-interest subimages of the key and test field are computed, and the translational offset (comprising horizontal and vertical displacements) between these subimages is estimated by selecting that offset that maximizes the correlation coefficient.

The areas of interest in the key and test fields are subdivided into blocks of pixels, for which cross-correlations are computed and offsets are estimated, using the previously estimated offset as initial estimates. The blocks are then further subdivided for computation of cross-correlations and offsets. The procedure of subdivision, cross-correlation, and offset estimation is repeated several times, yielding a hierarchy of block sizes (typically, down to smallest block size of 10 by 10 pixels) with corresponding correlation coefficients and offsets.

A data mask is constructed for the offsets at each level of the hierarchy to exclude those offsets that are deemed to be questionable because their correlation coefficients are below an arbitrary threshold value. The final offsets for the test field are calculated as weighted averages of the unmasked offsets for all block sizes; the weights are proportional to the sizes of the blocks. The data mask and the multiplicity of data from different parts of the area of interest help to reduce errors caused by parallax.

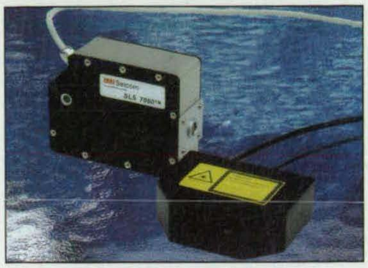
The rotation and dilation of the test field relative to the key field are estimated from the curls and divergences, respectively, of unmasked offset vectors. Statistical outliers (beyond one standard deviation) of curl and divergence values are masked out. The final offsets, rotation, and dilation are used to transform the test field into an output field that matches the key field in position, orientation, and magnification. The entire process is then repeated for each subsequent test field, using the offsets from the preceding field as initial guesses to reduce the ranges of offsets that must be searched for maximum correlation coefficients.

This work was done by David H. Hathaway and Paul J. Meyer of **Marshall Space Flight Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at (256) 544-5226 or sammy.nabors@msfc.nasa.gov. Refer to MFS-31243.

New Products

Product of the Month



Specular Reflective Sensor

LMI Selcom, a group company of Laser Measurement International, Inc. (Detroit, MI), presents a new series of non-contact, laser-based industrial gauging sensors. The highly specialized Class II LMI Selcom SLS 7000 Specular Reflective Sensor has a precise 10 nm over a 1 mm measurement range, 16 kHz sample rate, and features a small 10 to 20 micron visible laser spot that enables profiling of intricate target structures such as miniscule cracks and grooves. The sensor has a built-in digital processor for data averaging and filtering which is contained in a separate controller that easily interfaces with the sensor head. The SLS 700's imaging optics, integrated electronics, mechanical layout and conditioned electronic signal provide suppression of speckle noise and target structure influences.

For Free Info Circle No. 760 or Enter No. 760 at www.nasatech.com/rs

LED Measurement Tool

The OL 770-LED by Optronic Laboratories, Inc. (Orlando, FL) is a CCD-based, high-speed multichannel spectroradiometer capable of 25+ spectral scans per second. The instrument is capable of all critical measurements of LED components including optical power, color and goniometric measurements. The instrument's lightweight, small foot print design makes it suitable for use in production environments. The OL 770-LED was designed in accordance with CIE Publication 127 and is fully compliant.

For Free Info Circle No. 761 or Enter No. 761 at www.nasatech.com/rs

Digital Oscilloscope

LeCroy Corporation's (Chestnut Ridge, NY) WaveMaster oscilloscope is designed for next-generation waveform measurement and analysis, not just viewing of signals. The oscilloscope can capture very high-speed signals (up to 5 GHz bandwidth) and provide sophisticated measurements by using a patent-pending streaming architecture called X-Stream. X-Stream allows users to add customized parameter measurements or waveform functions into the processing chain of the oscilloscope.

For Free Info Circle No. 762 or Enter No. 762 at www.nasatech.com/rs

3D Scanners

Riegl USA (Orlando, FL) introduces the LPM series of 3D scanners that combine Riegl laser measuring technology and a lightweight, easy to use design for efficiency in applications such as 3D measurement, inspection, and modeling. Options include hemispheric scanning, automated or manual operation, reflectorless ranges to 2500 m, accuracy in the millimeters, and a comprehensive 3D data acquisition software package operable from a laptop PC.

For Free Info Circle No. 763 or Enter No. 763 at www.nasatech.com/rs

Spectroradiometer Contact Probe

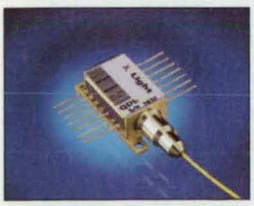
Analytical Spectral Devices (Boulder, CO) now offers a new accessory for its FieldSpec Pro® family of spectroradiometers. As seen on PTB's cover, the High Intensity Contact Probe features an internal light source that minimizes errors associated with stray light and allows users to measure reflectance with a higher signal-to-noise ratio. FieldSpec spectroradiometers are designed to collect solar reflectance, radiance, and irradiance measurements. Applications include mining, optical remote sensing, plant physiology, and geology.

For Free Info Circle No. 764 or Enter No. 764 at www.nasatech.com/rs

Argon Ion Laser for Digital Photofinishing

The LGK 7890 Dual-Line-Argon Ion Laser (Blue/Green) by LASOS Lasertechnik GmbH (Germany) was developed according to digital photofinishing requirements. This laser tube features wavelengths of 454.5 nm/457.9 nm with nominal output power of 4 mW; wavelength of 514.5 nm with nominal output power of 10 mW; and a beam diameter of 0.65 mm or 0.69 mm. LGK 7890 meets the relevant safety requirements of UL and CSA.

For Free Info Circle No. 765 or Enter No. 765 at www.nasatech.com/rs



Narrowly Tunable DFB Laser Module

The Lambda Light narrowly tunable distributed feedback (DFB) laser by Quantum Devices, Inc. (Yorba Linda, CA) can serve as a primary or spare source laser module for point-to-point WDM, low speed wavelength routed networks, optical add/drop, and precision test/measurement applications. The module is available in both a CW (up to 15 mW power) and DM version (up to 2.5 Gb/s with over 5 mW of peak optical output power). Available wavelengths span the full C-band.

For Free Info Circle No. 768 or Enter No. 768 at www.nasatech.com/rs

Program for Tracking Air-Purification Cartridges

The Cartridge Automated Reliance Tracking (CART) computer program enables authorized requesters associated with NASA to gain access to the most recent tracking data on LiOH-based air-purification cartridges used during space-shuttle flights. CART could also be adapted to suit the needs of other organizations in disseminating tracking data to geographically dispersed users. The information provided by CART includes the location and flight status of each cartridge, every step in the processing of the cartridge, and the statuses of all chemicals consumed in the processing. Prior to the development of CART, reports on the statuses of cartridges were prepared manually in Kennedy Space Center's LiOH laboratory on request and transmitted by facsimile — a slow, labor-intensive procedure. CART utilizes Oracle Forms and Tarantella Web software. Cartridge-tracking data are now stored on a central server computer and made available in a series of reports that are accessible to authorized requesters in real time via the World Wide Web.

This program was written by Christopher L. Ehrenfeld and Stephen M. Schneider of United Space Alliance for **Kennedy Space Center**. *For more information, contact the Kennedy Commercial Technology Office at 321-867-8130.*
KSC-12179

Software for Implementing Fuzzy Logic on Microcontrollers

Fuzzy Inference System Translator (FIST) is a computer program that facilitates the implementation of fuzzy-logic software on commercial or other viable microcontrollers. In the original application for which FIST was developed, there was a need to implement plant-growth-chamber (PGC) temperature-and-humidity controllers that had been developed within the MATLAB Fuzzy Logic Toolbox software system. In this application, fuzzy membership functions were specified for the temperature and relative-humidity signals, and a set of weighted inference rules was developed from experience and working knowledge of an environmental chamber, containing the PGC, in which the temperature and humidity were to be controlled. First-order models of PGC dynamics, based on the temperature dependences of heat-transfer rates and water-vapor pressure, were used with SIMULINK (mathematical-modeling software compatible with the MATLAB software) for rapid prototyping of a fuzzy inference system. All the information relevant to the controller thus developed are contained in a MATLAB fuzzy-inference-system file. The role of FIST in the development of the present controller or a similar controller is to extract the relevant information from this

file and process it into machine code that is executable on a specified microcontroller.

This program was written by Bill Taylor of New Mexico Highlands University for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

New Mexico Highlands University
Department of Engineering
National Avenue
Las Vegas, NM 87701

Refer to KSC-12145, volume and number of this NASA Tech Briefs *issue, and the page number.*

Software for Constructing a Facility-Management Database

Facility Management Tracking System (FMTS) is a computer program for constructing an integrated database that defines any event in a managed facility. FMTS provides a simple user interface for entering all relevant data connected to the event. The entered data, as displayed and processed by FMTS, are used by the facility manager to determine the status of the event, control processing steps and to verify other information about the event, approve the control points of the event, and ultimately close out the event. This process assures the requirements for the facility manager's authority over, and accountability for, meeting health and safety in the facility with a certifiable audit trail. The data can then be exported by electronic mail to other database systems maintained by organizations that are responsible for various systems within the facility. FMTS can be executed on standard personal computers and is compatible with commercial off-the-shelf server/client computer systems. The FMTS is designed to integrate modified versions of FMTS into database programs used by a variety of government and commercial organizations that have complex facility-management responsibilities.

This program was written by Thomas E. Diegelman of **Johnson Space Center**, *Jeannie Pullen of Science Applications International Corp., and Charles Shultz and Price Lewis of United Space Alliance. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*
MSC-23284

Software Implements Telemetry Protocols

The CCSDS Telemetry and Telecom Software Library provides a reference implementation of the Consultative Committee for Space Data Systems (CCSDS) international protocol standard for the transmission and reception of telemetry and telecommand data in radio communications with spacecraft. The library supports the full set of uplink and downlink virtual channels. It includes a frame-acceptance and -reporting mechanism (FARM) that supports a sliding window specified in the CCSDS standard, with routines for specifying the window width. The FARM generates CCSDS-standard command link control words (CLCWs) that indicate the state of the FARM. Routines for incorporating the CLCWs into downlink telemetry streams are included. Test drivers for showing how the library functions within the context of an application program are also included. The library has been written in the C programming language for execution on various computers running the SunOS4, SunOS5, AIX, and VxWorks operating systems. Makefiles that can be tailored for other computers and operating systems are included. Both source code and documentation are provided on the distribution medium, which is a tar file.

This work was done by Steven Allen of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20419.

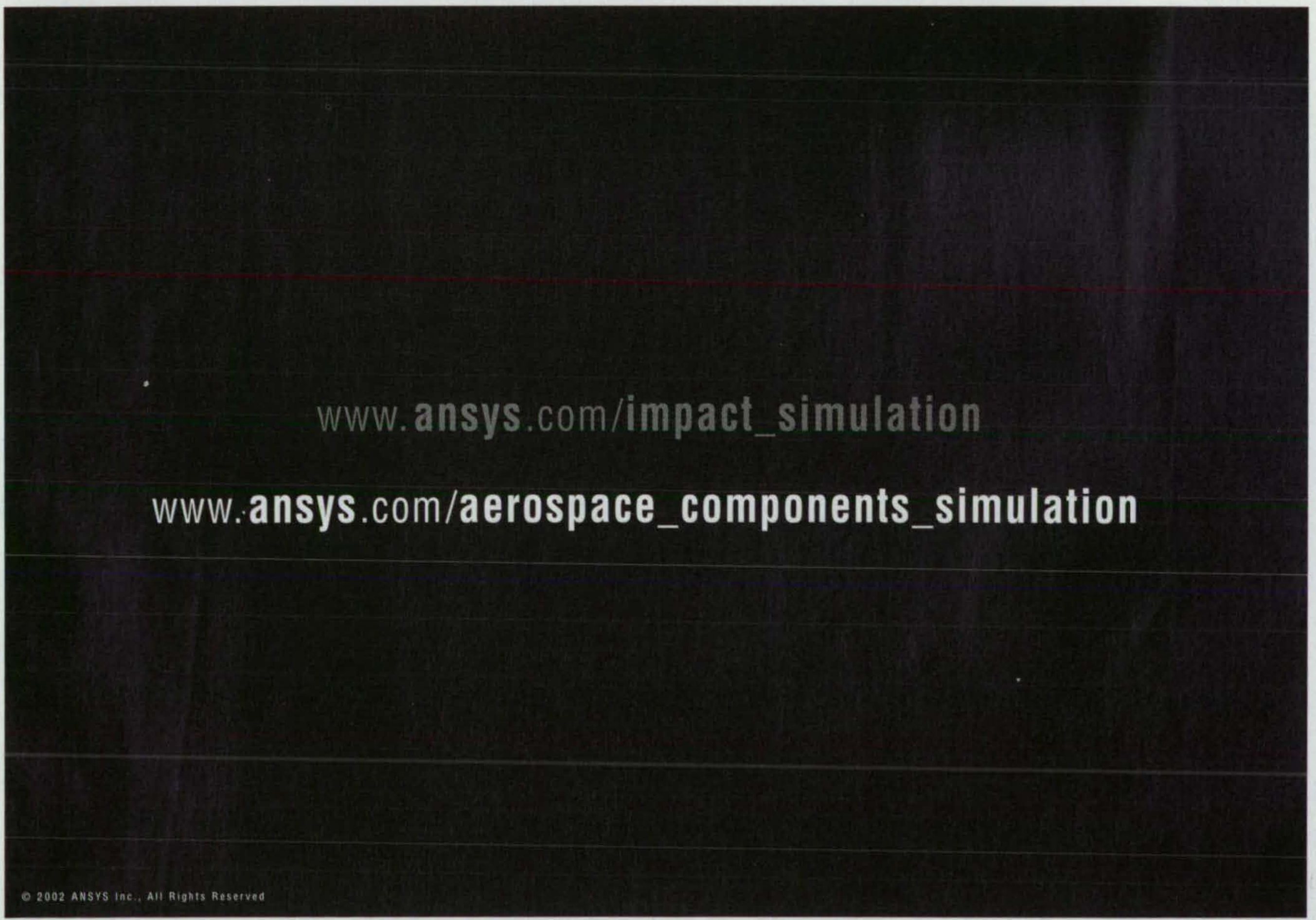
Software for Parallel Processing of Telemetry

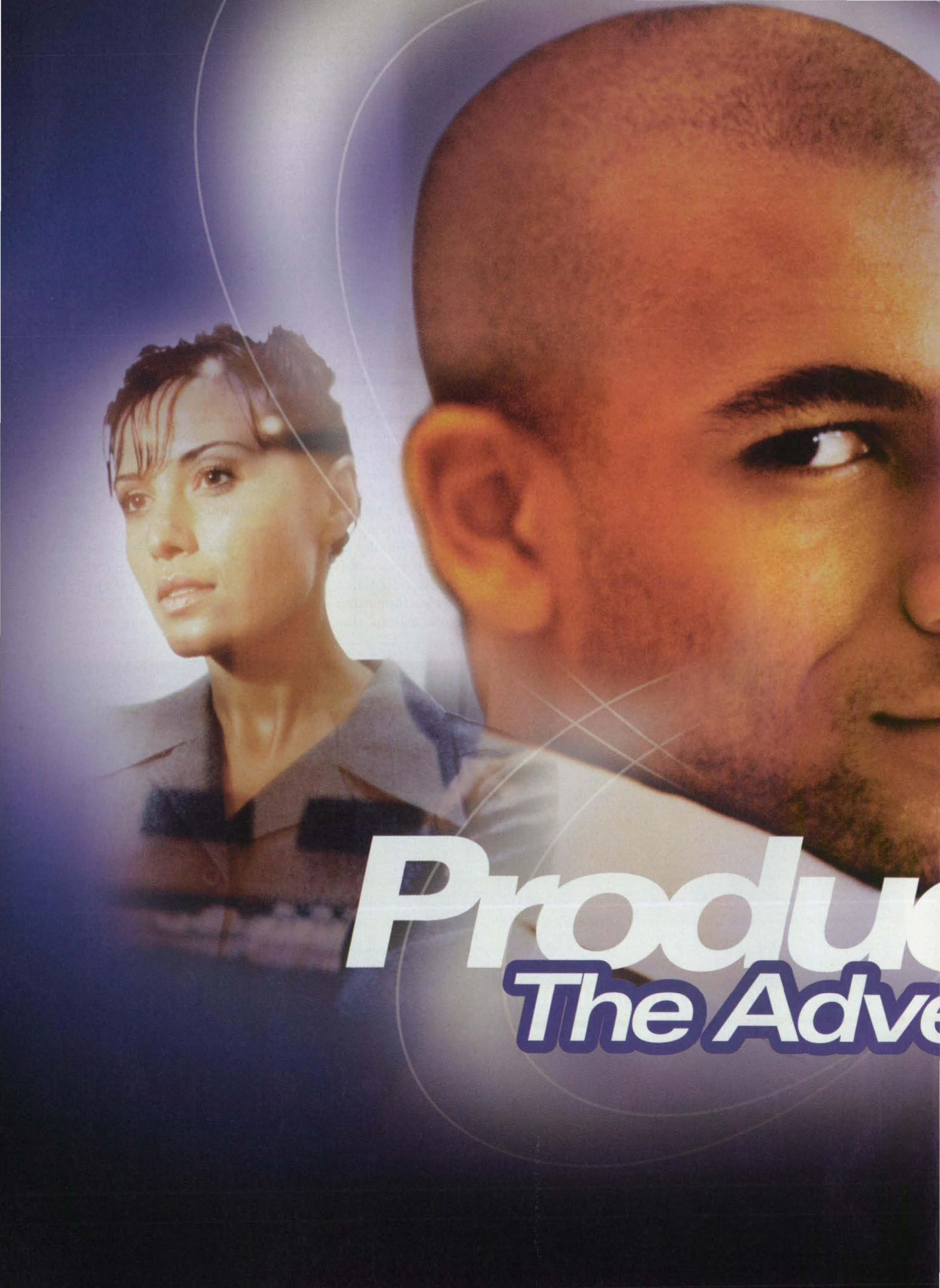
Parallel Telemetry Processor (PTEP) is a high-speed, robust, extensible, Java-language computer program that (1) enables the parallel processing of a serial stream of telemetric data and (2) generates a graphical display for monitoring the processing. Originally intended for application to spacecraft telemetry, PTEP could also be applied to the processing of data from other complex, heterogeneous systems that generate serial data streams. PTEP provides for multithreaded dispatching of tasks and accommodates the integration of other data-processing application programs into the processing pipeline. The PTEP graphical display is a color-coded flow chart with arrows that indicate the progress of each packet through processing steps. Also represented on the flow chart are intermediate data products and processing steps in which errors occur. Packets that cause processing errors are stored in an error queue for later review while the system continues to process new packets. At any time, a user can obtain detailed information about a processing error, correct the error, and resume processing of the affected packet.

This work was done by Jeffrey Norris, Eric Baumgartner, and Paul Backes of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21223.

(continued on page 50)

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Engineering and Design had labored in isolation.
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A PRODUCTION OF PTC. ALL CHARACTERS AND EVENTS ARE INTENDED TO PUT ENGINEERS AT THE CENTER OF PRODUCT DEVELOPMENT. ©2002 PARAMETRIC TECHNOLOGY CORPORATION. PTC AND ITS LOGO

Software for Global Forecasting of Winds and Waves

The WorldWinds™ software system generates high-resolution global weather forecasts, with emphasis on wind and ocean-wave vectors, in nearly real time. WorldWinds™ was developed primarily to serve organizations and individuals needing accurate forecasts for scientific, safety, or economic reasons. WorldWinds™ accepts input data from multiple satellite sources: the TOPEX altimeter, the ERS-2 scatterometer, the QuikScat scatterometer, and the SSM/I microwave radiometer. The software takes those parts of the data that pertain to wind, wave, and other weather observations, combines them with observational data from National Weather Service, and feeds them into two numerical models of weather: the Penn State MM5 model and the Harris Quasi-Lagrangian model. These models generate superior forecasts of wind and wave vectors and other weather variables for periods from 12 to 72 hours. WorldWinds™ is unique in that it can forecast winds over the entire surface of the Earth, producing a seamless global weather map every hour of every day. Data can be given at spatial grid intervals that range from 120 to as little as 3 km. Both spatial and temporal scales can be adjusted to satisfy the needs of clients.

This program was written by Elizabeth L. Valenti and Patrick Fitzpatrick of WorldWinds, Inc., and Samuel W. McCandless, Jr., and Barton Huxtable of User Systems, Inc., for **Stennis Space Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

WorldWinds, Inc.
John C Stennis Space Center
Bldg 1100, Rm 1125
Stennis Space Center, MS 39529

Refer to SSC-00109, volume and number of this NASA Tech Briefs *issue, and the page number.*

Software for Modeling Spacecraft Electric Power

Multi-Mission Power Analysis Tool (MMPAT) is a computer program for constructing computational models of the generation, storage, consumption, and flow of electric power in a spacecraft. Heretofore, such modeling has been accomplished by means of unique software for each application. In contrast, MMPAT offers a generic capability for constructing models for diverse applications, thereby potentially reducing development time and cost. MMPAT includes, principally, modeling algorithms and software for a graphical user interface (GUI). The modeling algorithms are encoded in the C programming language because C is commonly used and handles large sets of data fairly well, and because programs written in C can be readily attached to other programs. The GUI software is written Tcl/Tk, which is a scripting language. Tcl/Tk was chosen because it is portable among operating systems, includes a socket interface for connecting to external programs, has the look and feel of a traditional Windows application program, and can be used gratis. Together, the set of algorithms and the GUI software have proven to be a powerful combination that can be compiled into a single executable program.

This program was written by Roy Gladden and Mark Kordon of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30191.

Pressure-Balanced, Low-Hysteresis Finger Seal

Pressure balance would be altered to reduce a hysteretic variation of leakage.

John H. Glenn Research Center, Cleveland, Ohio

A second-generation design for a finger seal has been proposed to reduce a hysteretic effect that gives rise to increased leakage in a first-generation finger seal. As explained below, the second-generation design provides for balancing of pressure drops along the flow paths within the seal in such a way as to reduce a friction force believed to cause the hysteresis.

Like a labyrinth or brush seal, a finger seal is used (typically in a gas turbine) to minimize a leakage flow along a rotating shaft. A finger seal partly resembles a brush seal in appearance and function, but costs only about one-fifth as much.

Instead of the random array of fine wires found in a brush seal, a finger seal contains a stack of precisely photoetched sheet elements. The photoetched details of the sheet elements are series of intricate geometrical features repeated at small intervals along the circumference at the inner diameter (see Figure 1.) The key features are slender, curved beams (the fingers) with contact pads at their tips. The fingers spring-load the contact pads into gentle contact with the shaft.

Another key feature is a series of pairs of holes, into which rivets are inserted

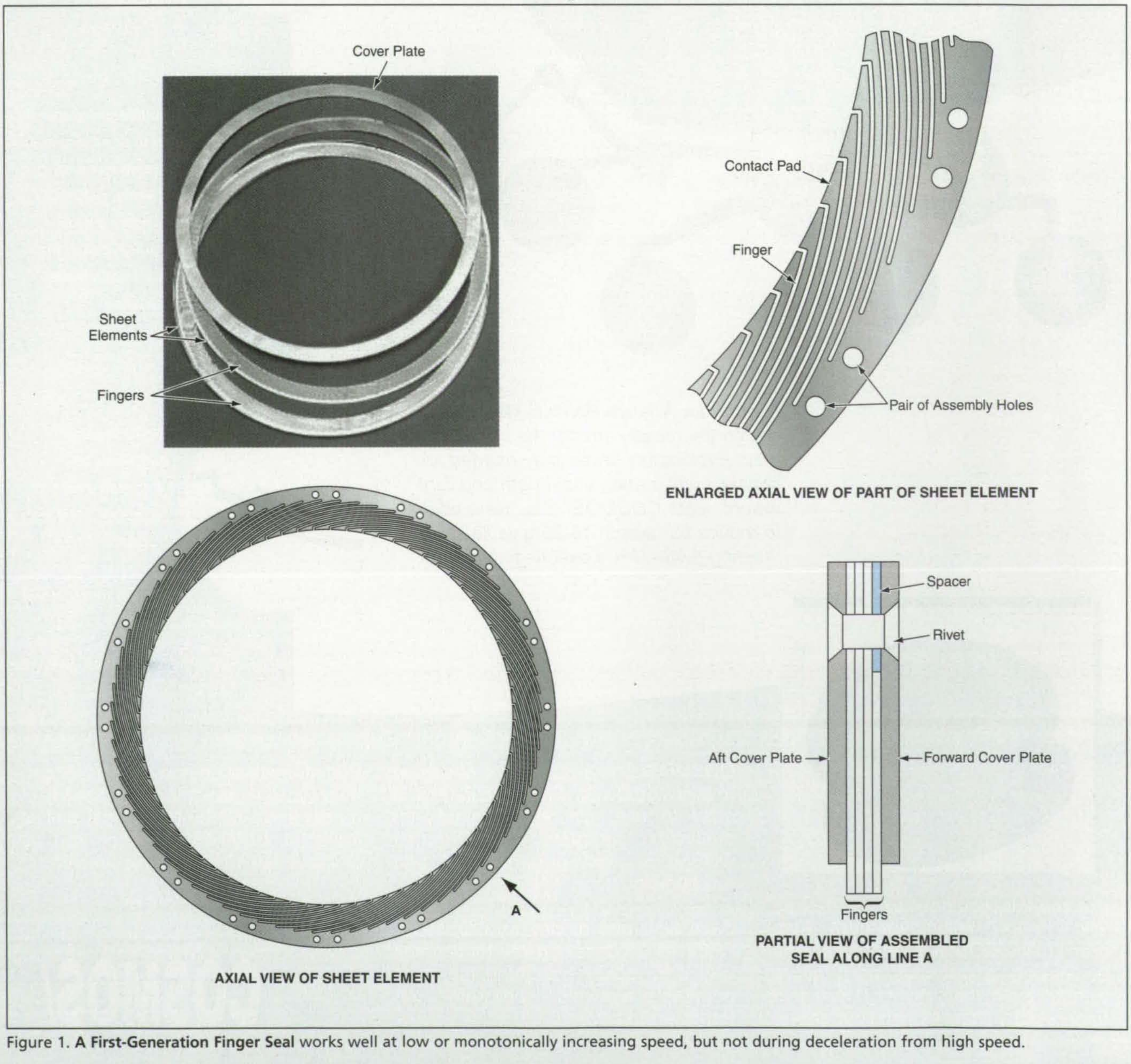

Figure 1. **A First-Generation Finger Seal** works well at low or monotonically increasing speed, but not during deceleration from high speed.

Technologies & Technology Needs

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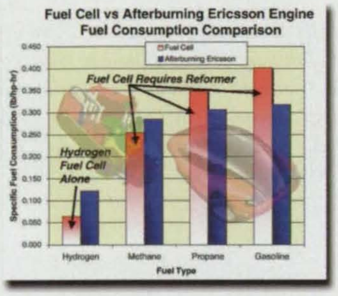
Afterburning Ericsson Cycle Engine Low-Cost Fuel Cell Alternative

The new Afterburning Ericsson Cycle (AEC) engine features a unique, patented, integrated combustion/engine process. Key to its success is its newly developed, patent-pending recuperator – a heat exchanger that recovers over 90% of the exhaust heat for higher thermodynamic efficiency and unmatched engine performance exceeding any conventional combustion engine or available fuel cell alternatives. This remarkable engine has virtually no burner efficiency loss because there's no external burner; it provides complete, continuous combustion, obtaining nearly the full heating value of the fuel. And, unlike fuel cells, it can run on any available fuel, including gasoline, methane, and propane.



The AEC engine does not require costly pollution controls and is easy and inexpensive to build, requiring nothing more than a modestly equipped machine shop capable of rebuilding an automobile engine. Its simple construction enables even a small manufacturer to produce engines for tomorrow's power market.

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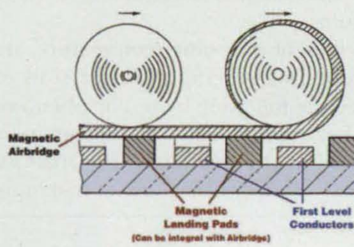
New Low-Cost, Single-Substrate Flat-Panel Display

To improve plasma flat-panel technology and create a more efficient, lower-cost display for a wide range of applications, this innovative concept uses a single substrate instead of the conventional two, precisely-spaced substrates. This single-substrate solution utilizes one set of conductors mounted or silk-screened to a transparent substrate with a second, beam-like conductor grid mounted orthogonally over the first, uniformly separated by spacing posts incorporated into the grid. This unique spacing method, called a microbridge or air bridge, eliminates the need for a two-sided enclosure and partial vacuum, substantially reducing manufacturing costs. No need for thick, expensive glass substrates, reinforced display designs, and costly alignment processes. As a result, conventional, large displays typically costing around ten thousand dollars might be produced in volume for around a thousand dollars.



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Can you solve these technology needs?

Looking for an Airflow Measurement Tool to Overcome the Observer Effect

This company needs a way to measure airflow through the ducts and plenums of both commercial and residential ovens without disrupting that airflow. The actual measurement apparatus must be small, and should interface with a PC for data logging and recording. The solution also should provide a way to visualize the airflows.

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during assembly of the seal. The holes are spaced such that when successive elements are alternately indexed to the holes, the empty spaces between the finger/pad subelements of each sheet element are covered by finger/pad subelements of the adjacent sheet element. Usually, a first-generation finger seal comprises four sheet elements, a spacer on the forward (high-pressure) side, and forward and aft cover plates.

The seal is fitted over a sealing land on the shaft with a small amount of interference and thus gentle spring loading. Flow through the seal is impeded by the staggered finger/pad features as well as by the radial contact between the land and the pads. The flexible fingers can give radially to accommodate shaft excursions and relative growth of the seal and rotor resulting from rotational forces and thermal expansion.

In tests at constant temperature and pressure, first-generation finger seals exhibited the following hysteretic phenomenon: Leakage remained close to an initial low level as the rotation of the shaft was ramped up from zero to a maximum speed of about 40,000 rpm, but then the leakage increased significantly as the speed was ramped from maximum down to zero. It has been conjectured that (1) as the speed increases, the fingers move out in response to a combination of centrifugal growth of the rotor, thermal mismatch, rotor runout, and other causes; and (2) as the speed decreases, the seal fingers do not spring back and instead become stuck in their radially outermost positions, so that the seal/shaft gaps become wider, allowing more leakage. It has been further conjectured that the reason the fingers become stuck in their outermost positions is that the force of friction between the aft cover plate and the fingers is greater than restoring spring force of the fingers.

The proposed second-generation design would reduce the pressure-drop force between the aft cover plate and the adjacent finger/pad subelements, thereby reducing the friction force believed to cause the hysteresis. A second-generation finger seal (see Figure 2) would comprise forward and aft cover plates, forward and aft spacers, and four sheet elements. By means of a series of radial and axial passages, the gap between the forward plate and the foremost sheet element would be connected to the gap between the aft cover plate and the aftmost sheet element. This connection would cause the intermediate pressure between the aft cover plate and the aftmost sheet element to track very closely the high pressure at the forward end. The aft cover plate would include a narrow dam in contact with the finger subelements of the aftmost sheet element. This dam would provide the seal between the intermediate pressure and the low pressure.

This work was done by Gulshan K. Arora and Donald L. Glick of Allied-Signal Aerospace Co. for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16840.

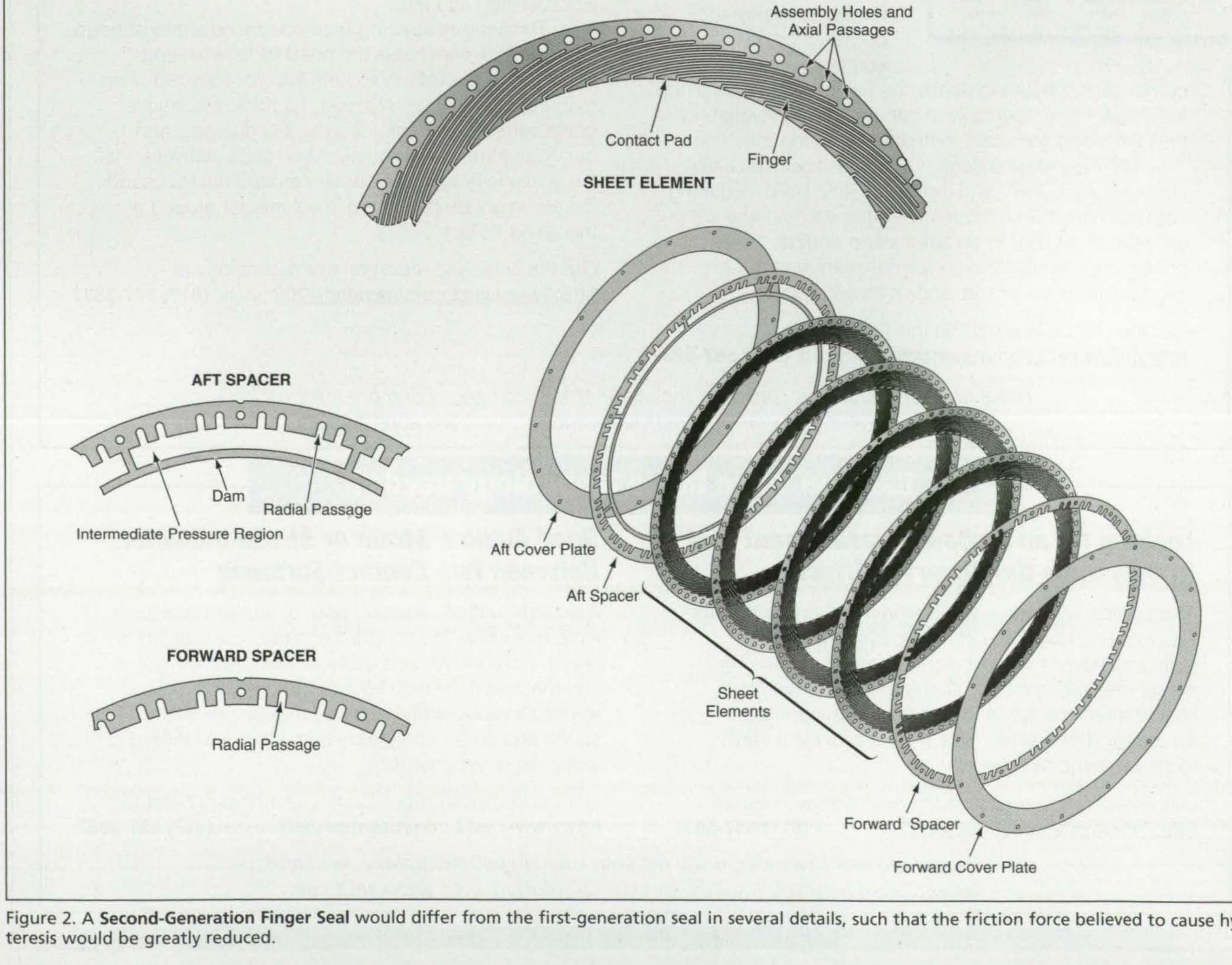


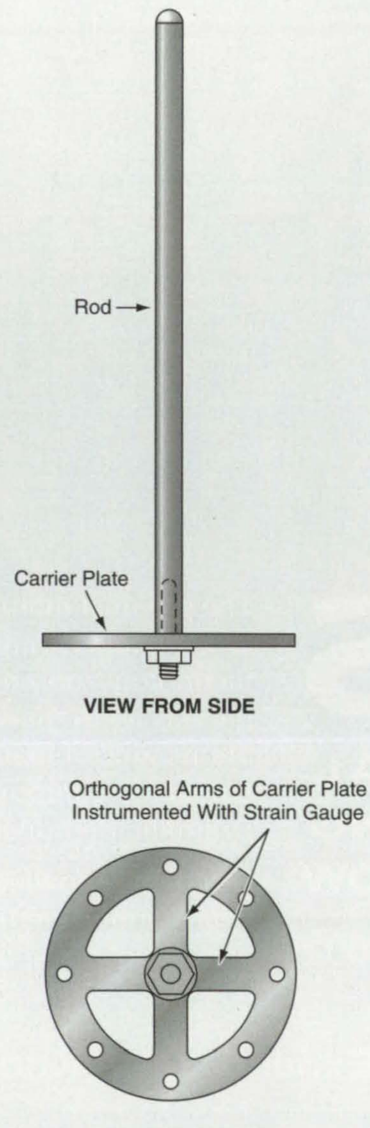
Figure 2. A **Second-Generation Finger Seal** would differ from the first-generation seal in several details, such that the friction force believed to cause hysteresis would be greatly reduced.

Instrument for Measuring Extreme Winds

This rugged instrument has no moving parts.

John F. Kennedy Space Center, Florida

An instrument is undergoing development for use in measuring both the horizontal direction and the horizontal speed of wind in the speed range from 60 to 300 mph (about 27 to 134 m/s) at a rate of at least 50 samples per second. The speed range of this instrument greatly exceeds that of conventional anemometers, encompassing speeds observed in hurricanes and tornadoes.



This **Strain-Gauge Anemometer** is based on strain-gauge measurement of bending in the orthogonal arms of the carrier plate. The bending is related in a known way to the wind load on the rod.

Unlike conventional anemometers, this instrument has a small exposure profile and contains no rotating mechanisms and, hence, is more rugged.

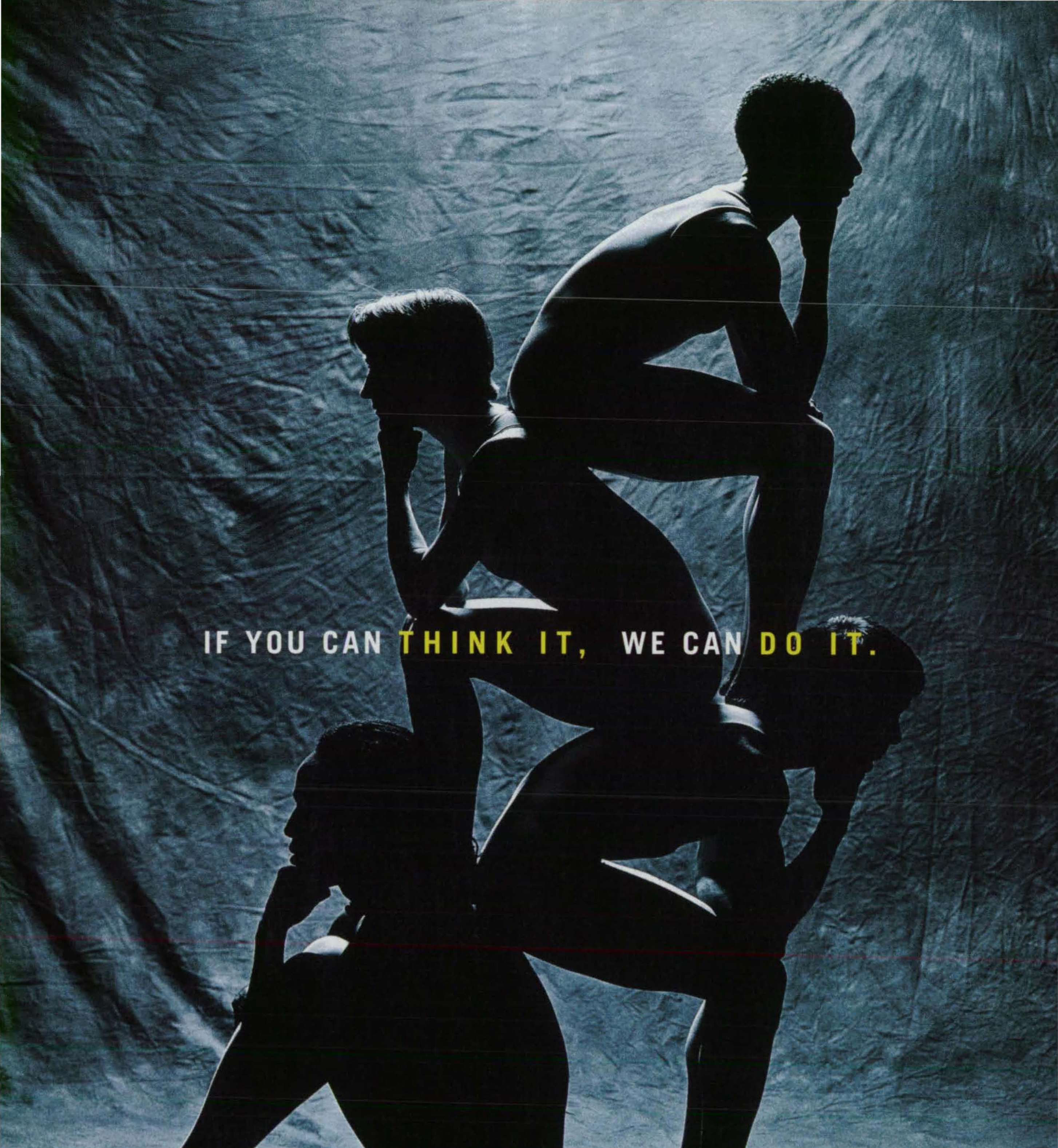
This instrument is based on measurement of the force exerted by wind on a stationary vertical rod. For the purpose of obtaining readings proportional to the wind force in two orthogonal horizontal directions, one end of the rod is attached to a cruciform carrier plate, the orthogonal arms of which are instrumented with strain gauges (see figure). The aerodynamic load on the rod causes the crossed arms to bend somewhat, and the bending is measured by the strain gauges.

The aerodynamic force on a rod in a cross flow is well understood and is a function of the Reynolds number. The force includes a steady component proportional to drag, which, in turn, is proportional to the square of the wind speed. In addition, over a certain range of the Reynolds number, vortices are periodically shed from the rod, giving rise to a side-to-side oscillating force, the frequency of which is linearly proportional to the wind speed. Hence, the strain-gauge outputs include steady drag components and oscillatory vortex-shedding components that are related to the wind velocity in known ways.

A signal-processing technique has been devised to extract, from the steady and oscillatory components of the strain-gauge outputs, two independent indications of the wind speed. These two indications can then be used to obtain an optimal estimate of the wind speed. When fully developed, the instrument will also include signal-processing electronic circuitry and data-storage circuitry. An internal battery power supply is an important element of the design inasmuch as commercial power would be unreliable in a major storm and should possibly make the instrument more vulnerable to damage by lightning.

This work was done by Jan Zysko of **Kennedy Space Center** *and Stan Starr of I-NET, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*

KSC-11886


IF YOU CAN THINK IT, WE CAN DO IT.

Mechanized Harvesting of Plants in a Controlled Environment

John F. Kennedy Space Center, Florida

The proposed Plant Harvesting Mechanization System (PHARMS) would comprise machinery and controls for semiautomated harvesting of plants grown in a controlled environment. The PHARMS was conceived as a prototype of harvesters to be incorporated into life-support systems of spacecraft and remote planetary bases, wherein plants would provide food and contribute to recycling of air and water. On Earth, PHARMS-like systems could reduce the labor of harvesting plants from protected agricultural systems in which special fruits and vegetables, herbs, ornamental plants, and mushrooms are grown. At harvest time, the PHARMS would be moved from storage to a location near the plant-growth chamber. There, it would be unfolded from a compact configuration, then prepared for operation by setting of control parameters and mechanical alignment with the chamber and plants. In operation, the PHARMS would pull plant trays out of the chamber and remove plants from the trays. Then it would subject the plants to a variety of other processes, depending on the crop: Examples of such processes include drying, cutting, chopping, stripping of seeds from stalks, threshing, separation of roots from stalks or vines, breaking pods to extract seeds, and pneumatic separation of seeds from chaff.

This work was done by Jeffrey T. Iverson, Chad Ehle, Andrea Hill, and Robert Birnschein of Orbital Technologies Corp. for **Kennedy Space Center.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Thomas M. Crabb
Orbital Technologies Corp.
1212 Fourier Drive
Madison, WI 53717
Tel No.: (608) 827-5000
E-mail: crabbt@orbitec.com

Refer to KSC-12143, volume and number of this NASA Tech Briefs *issue, and the page number.*

Emergency Landing Using Thrust Control and Shift of Weight

Landing with control surfaces and engines on one side inoperative may be possible.

Dryden Flight Research Center, Edwards, California

Normally, the damage that results in a total loss of the primary flight control of a transport airplane, including all the engines on one side, would be catastrophic. Dryden Flight Research Center has conceived of a method of responding to a total loss of hydraulic pressure and failure of engines on one side: An emergency controller would utilize the engines that are still working on the other side, along with transfers of fuel among tanks to effect lateral shift of the center of gravity (CG), in order to steer the airplane to an emergency landing.

Many occurrences have made it necessary to use engine thrust to supplement or even replace the normal flight controls of aircraft. Most of these occurrences have resulted in crashes, in which a total of more than 1,200 lives have been lost (see "Throttles Land Disabled Jet" by Michael Dornheim, Aviation Week & Space Technology, September 4, 1995, pages 26 and 27).

Dryden Flight Research Center has developed a propulsion-controlled aircraft (PCA) system, in which computer-controlled thrust provides an emergency control capability without using any of the normal control surfaces. Using a PCA system, an F-15 and an MD-11 airplane have landed without using any moving control surfaces. In all the cases studied, the thrust of the engines on both sides of the airplane was available. Figure 1 shows the first MD-11 PCA landing accomplished by use of thrust modulation with all the engines working and no moving control surfaces.

Figure 1: An **MD-11 Airplane** is shown here landing with thrust control only (that is, with control surfaces not moving).

Consider an airplane on which a bomb blast has disabled the hydraulics (making the control surfaces inoperative) as well as the engine or engines on one side. Could an emergency controller be designed to land the airplane? A preliminary investigation has shown that one wing engine can be operated to obtain limited flight control if the lateral center of gravity (CG-Y) is shifted toward the wing with the working engine. Simulations of the MD-11 with all conventional flight controls inoperative and a wing engine inoperative have shown positive control capability within the available range of CG-Y offset. Simulations of such four-engine airplanes as the B-720 and B-747, have also shown positive control capability within the available ranges of CG-Y offsets.

U.S. Patent 6,126,111 documents this emergency controller. On large commercial airplanes, engines are usually located under both wings, either singly or in pairs, and large amounts of fuel are carried for long journeys. The

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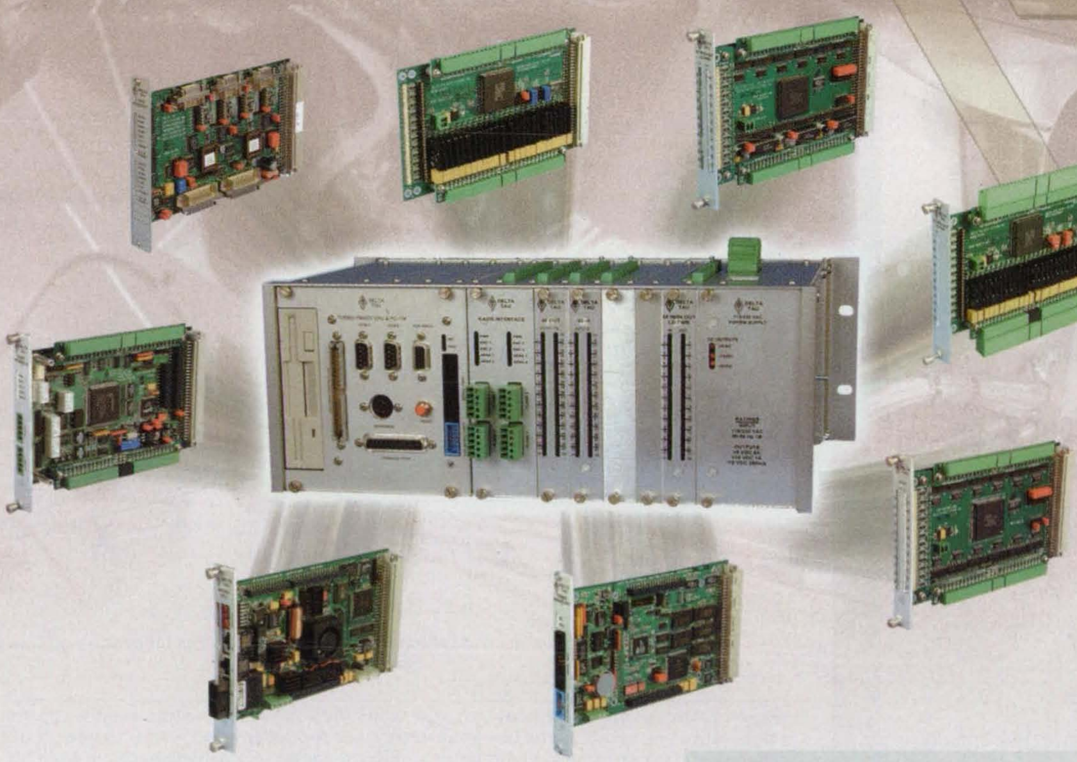

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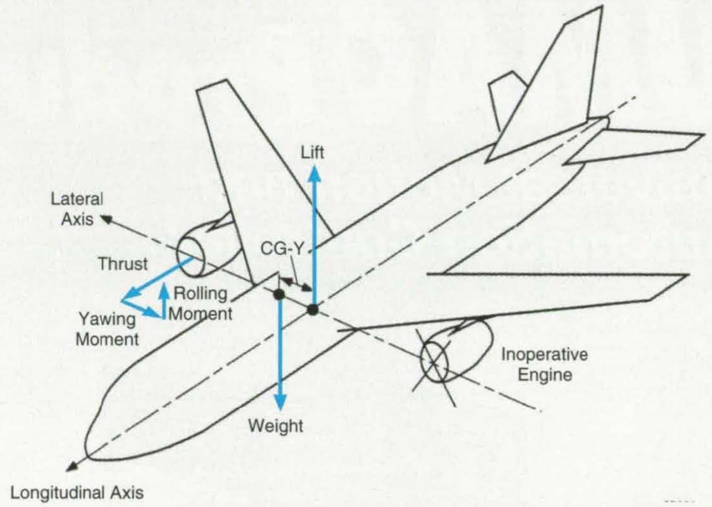
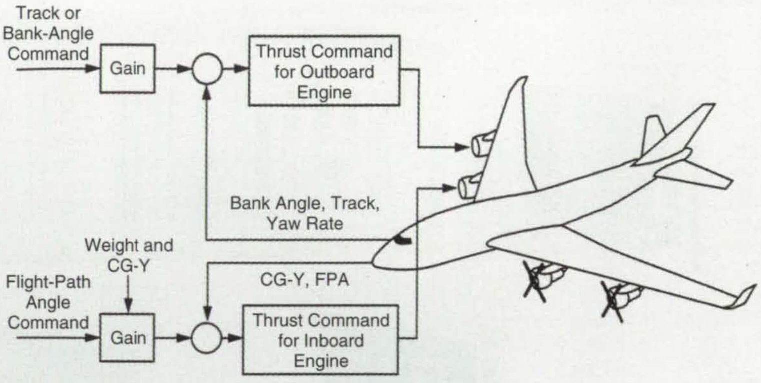


Forces and Moments on an Airplane With a Wing Engine Inoperative and a CG-Y Offset



Emergency Longitudinal and Lateral Control With Two Engines Inoperative on One Side and a CG-Y Offset

Figure 2. The **Asymmetric Forces** that arise when the engines on one side and the control surfaces are inoperative are countered by use of an emergency controller, which varies the thrust of the working engines and transfers fuel among tanks to shift the center of gravity toward the working-engine side.

fuel tanks are distributed throughout the wings and cargo sections of the airplanes. The transfer of fuel among the tanks of an airplane to shift its CG-Y is a well known and frequent practice.

Fuel can be transferred selectably and independently among all fuel tanks. On the MD-11 airplane, each wing tank holds 42,000 lb (≈19,000 kg) of fuel and the maximum CG-Y shift observed in tests was 45 in. (1.14 m) in 15 minutes, corresponding to an average rate of change of CG-Y of about 3 in. (≈7.6 cm) per minute. On the B-747 airplane the wing fuel capacity is 84,000 lb (≈38,000 kg) in each inboard tank and 30,000 lb (≈13,600 kg) in each outboard tank, and the maximum CG-Y shift observed was 70 in. (1.78 m).

The upper part of Figure 2 illustrates the case of an airplane with inoperative control surfaces and only one operating engine. The CG-Y is shifted toward the side with the working engine. The thrust of the operating engine creates yawing and rolling moments to counter the rolling moment resulting from the drag of the nonoperating engine. The lower part of Figure 2 depicts the emergency-control scheme. The results of simulations of the use of this control scheme on the MD-11 and B-747 have shown that level flight can be maintained. Increasing thrust rolls the airplane away from side of the working engine. Roll rates of 5°/s are typical. This control scheme makes it possible to align the airplane with the center line of a runway and, most likely, to have a survivable landing. Of course, practice landings in a simulator or during a high-altitude flight above a real runway are needed to increase the likelihood of a survivable landing.

This work was done by John J. Burken, Bill Burcham, and Jeanette Le of **Dryden Flight Research Center**.

This invention has been patented by NASA (U.S. Patent No. 6,126,111). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed the Patent Counsel, Dryden Flight Research Center; (661) 276-3720. Refer to DRC-96-55.

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High-Velocity, Pulsed Wire Arc Spray

Higher spray velocity should result in superior deposits.

Marshall Space Flight Center, Alabama

A high-velocity, pulsed wire arc spraying apparatus has been proposed and partly developed in an effort to improve the quality of coatings deposited by thermal spray techniques. In this apparatus, material from a wire arc is atomized and propelled toward a deposition substrate by a repetitively pulsed plasma jet. As explained below, this development is prompted by (1) the observation that the particle velocities attainable in traditional wire arc spraying are too low to enable the deposition of dense, high-quality coating materials that are often desired and (2) the expectation that higher spray velocities should result in superior coatings.

In traditional wire arc spraying, an arc is drawn between the proximate tips of two insulated metallic wires and the wires are continuously fed toward the arc as the arc consumes them. (Sometimes one of the wires is replaced by a nonconsumable electrode.) A steady stream of gas (usually compressed air) is directed through the arc to atomize the molten wire material in the arc and propel the resulting droplets toward a deposition substrate. One principal disadvantage of the conventional wire arc spray technique has been the low particle velocity obtained, generally limited to ≈ 250 m/s as a consequence of the fundamental physical nature of the steady gas stream. It is desirable to increase the velocity in order to minimize droplet cooling in the cold gas stream, to eliminate in-flight oxidation of the droplets, and to produce zero porosity coatings.

The UTRON Pulsed Wire Arc Spray device integrates the excellent accelerating characteristics of pulsed plasmas with the simplicity of wire arc systems. The basic approach is to replace the compressed gas stream used in conventional wire arc spray with a repetitive, high-pressure, high-momentum flux pulsed plasma jet. The plasma jet is generated by a so-called capillary arc discharge in a gas or liquid located between electrodes at

each end of a long narrow ceramic tube. It is called a capillary discharge due to the high length/diameter ratio, typically about 10 or so. The high-speed plasma jet exiting from a nozzle at the one open end of the capillary is oriented to aim the jet through the arc between the wire tips.

The plasma jet can be formed from a wide range of working fluids, but the work to date has utilized either cryogenic liquid argon or gaseous argon. Liquid argon can be injected as a thin stream into the capillary region either continuously or through fast-acting valves or check valves. The injection orifice, located at the rear end of the capillary, is sized to admit a quantity of liquid equivalent to room-temperature gas at up to 30 atm (~3 MPa). A high-voltage spark discharge triggers electrical breakdown through the gas or vaporizing liquid, which then triggers the main arc discharge along the length of the capillary. Highest performance is achieved with liquid injection since that introduces sufficient mass of gas to attain high pressure without exceeding temperature limits of the ceramic wall. The pulsed discharge quickly raises the pressure and temperature of the working fluid in the capillary to about 1 kbar (100 MPa) and 1 eV (11,600 K), resulting in a high-velocity jet exiting through the nozzle at the end of the tube.

The coating-material wires are positioned through holes in the expansion nozzle attached to the front end of the capillary tube. The arc discharge between the wires can occur either a few microseconds before or after initiation of the plasma jet discharge. In the latter case, the plasma jet itself provides a convenient breakdown path for the wire arc.

The pulsed plasma jet strips the molten metal from the wire tips, atomizes the droplets, and rapidly accelerates the resulting atomized metal droplets to speeds comparable to the plasma. These droplets are then deposited on a substrate or other piece of equipment. The entire process lasts about 100 to 250 μs and can be repeated hundreds of times per second.

The effectiveness of the pulsed wire arc spray device in atomizing and accelerating droplets derives from the extremely high-momentum flux (ρv^2) of the pulsed plasma jet. The high-momentum flux is achieved mainly by an order of magnitude increase in velocity v, but also by a similar increase in density ρ when liquid injection is utilized.

To date, the Pulsed Wire Arc Spray device has been operated at single pulse energies up to 4.2 kJ with liquid argon, and at repetition rates as high as 20 Hz at lower energy. Deposition rates as high as 2 kg/h were demonstrated, limited only by the available power supply. Experimental measurements established droplet velocities of up to nearly 1,500 m/s in acceleration distances as short as 3.2 cm, thus making this an ideal process for spraying the inner walls of confined regions (such as cylinder bores and pipes) where space is limited.

This work was performed by F. Douglas Witherspoon, Russell W. Kincaid, and Dennis Massey of UTRON Inc. for **Marshall Space Flight Center**. *UTRON has been awarded U.S. Patent 6,001,425 for this pulsed high-velocity wire arc spraying device. For further information about the current status of this invention, please contact Dr. Russell Kincaid or Dr. Douglas Witherspoon at UTRON at (703) 369-5552 or by e-mail at rwkincaid@erols.com. See also web page at www.utroninc.com.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (256) 544-0021. Refer to MFS-31491.

Software for Electromagnetic Detection of Buried Explosives

Data from a variety of sensors on different survey grids can be used.

NASA's Jet Propulsion Laboratory, Pasadena, California

U-HUNTER (also called "UXO-HUNTER") is a computer program that affords knowledge-based real-time sensor-fusion and display capabilities for detecting buried objects and materials of interest. U-HUNTER is intended especially for inferring the presence of buried unexploded ordnance and explosive waste from the readings of magnetic and electromagnetic sensors like those commonly used in geophysical surveys. U-HUNTER is also potentially adaptable to such other uses as detection of mines, medical imaging and diagnosis, detecting and monitoring buried pipes and cables, environmental monitoring, and geological surveys.

U-HUNTER can utilize data in a wide variety of formats. At present, it can accept and process the data from such sensors as magnetometers, synthetic-aperture radar systems, and time-domain pulsed eddy-current sensors. U-HUNTER has the potential for reducing (in comparison with prior sensor-data-analysis software) the rate of errors in the detection of anomalies (that is, unexploded ordnance or other phenomena of interest). U-HUNTER also has the potential for enabling better characterization and classification of detected anomalies. Envisioned applications of U-HUNTER include not only analysis of fresh data from continuing surveys but also re-evaluation of historical survey data to increase the level of certainty of detection of unexploded ordnance at sites where such surveys have already been performed. Fusion of multiple-sensor and/or multiple-survey data from the same site is also envisioned.

U-HUNTER contains unique subsystems that perform different functions, as follows:

- A data-enhancement subsystem preprocesses input data to condition them for analysis. One of the most powerful features of U-HUNTER is a fully integrated programming interface within the data-enhancement subsystem. This interface makes it possible to develop custom algorithms to preprocess and display the data to be fed as input to the analysis-engine subsystem mentioned below. U-HUNTER is flexible enough to

allow the import of any image or raw matrix data for analysis. This capability alone has proven to be most impressive in enabling users familiar with data from sensors of one type (e.g., magnetometers) to apply the analytical capabilities of U-HUNTER to data from sensors of another type (e.g., synthetic-aperture radar).

- An analysis-engine subsystem includes a version of ARTMAP, which is part of a previously developed neural-network software system. The analysis-engine subsystem is also expected to include ANFIS — a yet-to-be-developed program for implementing an adaptive neuro-fuzzy information software system for a secondary method of classification of anomalies.
- A subsystem called "3DKB" is dedicated to facilitation of the assimilation of the items of a three-dimensional knowledge base. The 3DKB items comprise the knowledge built up by a user from ground-truth data for the purposes of training neural and neuro-fuzzy software components within U-HUNTER. Dialog-type displays enable users to load 3DKB items for training of the ARTMAP-type neural networks for classification of anomalies.
- A visualization subsystem generates displays of geophysical data on three-dimensional-appearing surface models and two-dimensional color maps. The maps provide a capability for rapid visual inspection of a surveyed area. Deep-blue dots are placed at locations of local maxima of and magenta dots are placed at locations of local minima of quantities of interest. The user can customize maximum- and minimum-finding algorithms to obtain desired levels of discrimination. A subprogram called "3D Anomaly Viewer" enables users to see the shapes of found anomalies.

U-HUNTER has been found to perform robustly, both (1) when applied in real time at the survey-grid-interval level (<100 m by <100 m) and (2) when applied at the entire-site level after completion of surveys of sites ranging in size from 500 to 25,000 acres (2 to 100 km^2). U-HUNTER enables detection of anomalies at the 100-percent level, while keeping the incidence of false alarms down to the 2-percent level. It also provides for robust generalization to new sites without additional training or setup, and it minimizes the effect of reacquisition of data on postprocessing. It can perform robustly despite poor ground control; that is, it can tolerate errors of the order of grid intervals. Furthermore, U-HUNTER enables rapid synthetic resampling and interpolation of data to a spatial resolution relevant to the spatial distribution of unexploded ordnance, and enables resampling of data from multiple sensors to a common spatial scale.

Planned future development of U-HUNTER includes an extension of data-display capabilities to provide for overlays of planimetric data, aerial photography, and geophysical data. Other planned enhancements include extension of analysis subsystems to accommodate additional alterative classification methods and development of an improved user interface to make the U-HUNTER more accessible to the general geophysical community.

This work was done by Sandeep Gulati and Vijay Daggumati of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20808.

Aircraft Anti-Icing Systems Utilizing Induced Hydrophobicity

It should be possible to build lightweight, low-power, low-profile anti-icing systems based on this concept.

John H. Glenn Research Center, Cleveland, Ohio

Aircraft anti-icing systems of a proposed type would utilize static electric fields to reduce or eliminate the electrostatic forces that bond ice and water to metal surfaces. These would be lightweight, low-power-consumption, inexpensive systems that would be installed on the surfaces of wings and other critical airfoils. These systems would not intrude significantly into the interiors of airfoils; they would also not protrude from airfoil surfaces and thus would not disturb aerodynamics.

Many anti-icing systems now in common use are of the "weeping-wing" type: they mete out deicing fluids over airfoils. The reservoirs needed to store deicing fluids, the plumbing needed to distribute the fluids over the airfoil surfaces, and the fluids themselves impose severe interior-space and weight penalties on aircraft design and operation, and the fluids can exert adverse effects on the environments into which they are released. Some other anti-icing systems now in use are of the electrothermal type; the disadvantage of these systems is that they consume significant amounts of aircraft power. Yet another anti-icing concept that has been tried previously involves the use of such ice-phobic materials as polytetrafluoroethylene; this concept has met only limited success, and performance can be degraded through erosion of ice-phobic materials.

Three phenomena that contribute to the adhesion of ice are electrostatic attraction, covalent bonding, and the Van der Waals force. The electrostatic force is possibly the most significant. Because water and ice are polar materials, the alignment of their molecules is influenced by an electric field. Water adheres to a metallic surface because the molecular orientation is such that a positive charge exists on the water surface facing the metal and is attracted to a negative charge on the metal surface. On freezing, water molecules reorganize from a liquid to a crystalline structure that remains polar. Thus, ice adheres to the metal surface for the same reason that water does. In principle, the electrostatic part of the bonding force could be eliminated by applying an opposing dc electric field across the interface between the metal surface and the ice. In the proposed systems, the necessary electric fields would be generated by use of electrodes patterned on the airfoil surfaces to be protected. The fundamental research on the reduction of ice adhesion strength using an applied dc electric charge was conducted by Professor Victor Petrenko of Dartmouth's Thayer School of Engineering. Dartmouth College has patented the technology (U.S. Patent No. 6,027,075).

Systems of the proposed type would be attractive for use on general aviation

and commuter aircraft. These systems could provide safety margins for aircraft that inadvertently encounter icing conditions. An electrostatic anti-icing system could be activated prior to entering actual or potential icing conditions, without power or performance penalty. An electrostatic anti-icing system could also enhance the performance of an electro-expulsive or pneumatic-boot deicer by reducing or eliminating residual ice after each activation of the deicer.

This work was done by Jack Edmonds and Richard B. Ingram of Innovative Dynamics, Inc., for **Glenn Research Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16939.

Characterization of Heat-Flux-Gauge Calibration System

Phenomena that affect measurements are being investigated in detail.

Dryden Flight Research Center, Edwards, California

A project is underway in the Flight Loads Laboratory (FLL) at Dryden Flight Research Center to reduce the uncertainties in heat-flux measurements. The impetus for this project is provided, in part, by the observation that uncertainties in heat-flux measurements are large — often 10 to 20 percent or more. Further impetus is provided by the fact that heat-flux calibration facilities being developed at the National Institute of Standards and Technology (NIST) operate at heat fluxes well below the levels which can be achieved during high-speed flight. Thus, a heat-flux-gauge user interested in such high fluxes has only two options: (1) take the gauge manufacturer's calibration on faith or (2) develop and understand his or her own calibration process.

The broad objectives of the project are:

- Characterize a radiant-heat-flux gauge-calibration system in the FLL (see Figure 1) in order to quantify and, if possible, reduce calibration uncertainty and
- Be able to demonstrate to customers that the FLL personnel understand the heat-flux-gauge calibrations that they perform.

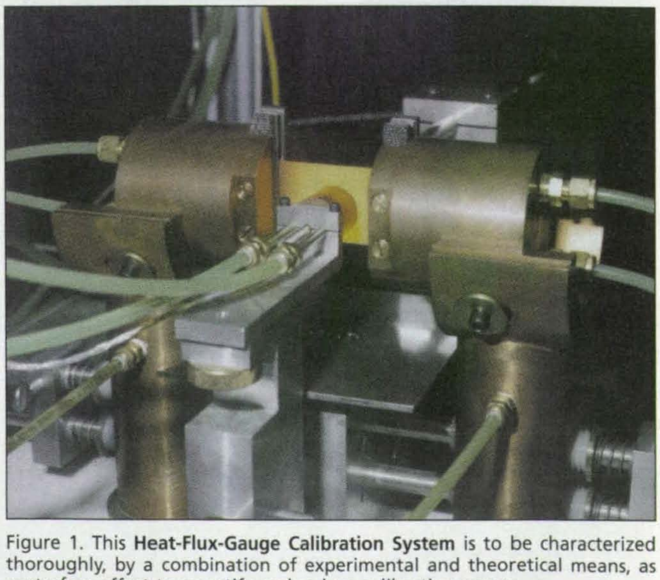


Figure 1. This **Heat-Flux-Gauge Calibration System** is to be characterized thoroughly, by a combination of experimental and theoretical means, as part of an effort to quantify and reduce calibration errors.

The first phase of the project involves a thorough characterization of the calibration system, which uses an electrical resistance heated graphite plate as a heat source, in order to reach the first stated objective. Future phases of the project will involve development of methods for using gauges calibrated in this system in radiant-heating tests performed in the FLL and in flight.

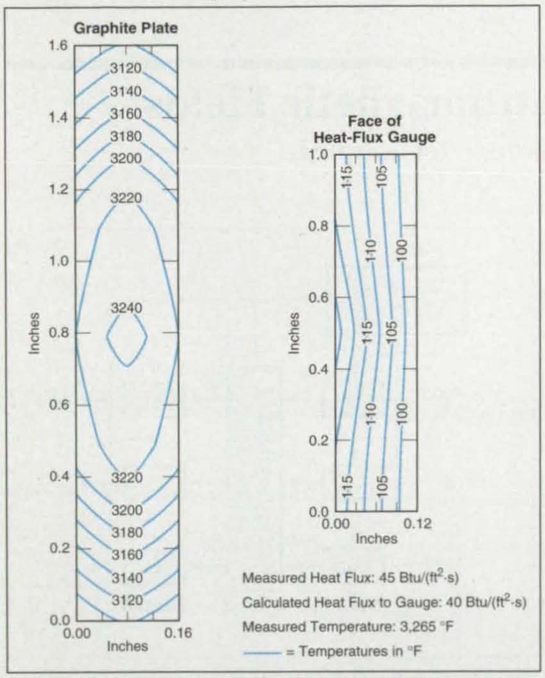


Figure 2. The **Isotherms in the Rectangles** that represent a graphite plate and a nearby heat-flux gauge were computed for a test case, by use of a two-dimensional mathematical model.

The following is a partial list of technical challenges that must be met in the project:

- Determine the effects of erosion of graphite plates,
- Determine the effect of convection on the heat flux gauge, and
- Determine the effect, upon the distribution of absorbed heat flux, of the distance between a graphite plate and heat-flux gauge.

Thus far, an initial two-dimensional mathematical model of heat flux and temperature distribution has been developed for a vertical cross section of the graphite plate and heat flux gauge (see Figure 2). The rectangles in Figure 2 representing the graphite plate and heat flux gauge are in their proper relative positions and orientations but are not shown to scale. The results of initial experiments include heat fluxes within 10 percent of those predicted by the model. An initial graphite plate erosion model has predicted plate erosion within 5 percent of the measured values.

Planned future efforts include the following:

- Refinements of the two-dimensional model, including an improved erosion model and incorporating internal details of a circular foil heat flux gauge;
- Refinement of experiments to collect such additional detailed information as rates of flow and temperatures of gauge-cooling water and distributions of temperature in graphite plates;
- Expansion of the model to three dimensions; and
- Determination of experimental heat fluxes by use of alternative physical principles.

This work was done by Tom Horn of **Dryden Flight Research Center** *and Shanjuan Jiang and Vijay Dhir of the University of California. For further information, contact the Dryden Commercial Technology Office at 661-276-3689.*

DRC-98-77

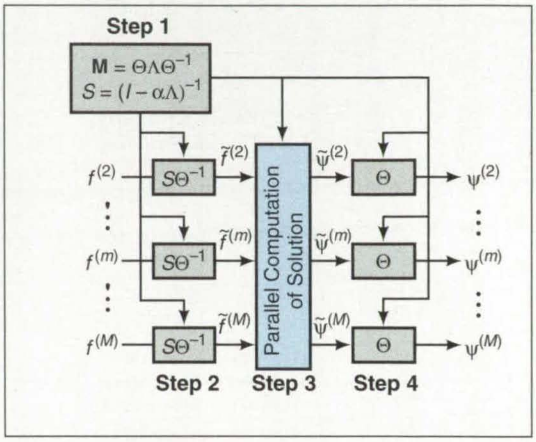
Massively Parallel Computation of Electromagnetic Fields

Maxwell's equations are solved by fully implicit finite-difference techniques.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of massively parallel computation on supercomputers has been developed to facilitate numerical simulation of electromagnetic fields in the vicinities of electrically large and complex radiating and scattering objects. In this method as in methods developed previously for the same purpose, Maxwell's equations are solved by use of finite-difference approximations in both space and time. However, unlike in the other methods, this method is not limited to implicit (and thus parallel) solution in space with explicit (and thus sequential) time stepping with small time steps to ensure numerical stability. Instead, this method provides for parallel solution for all time steps, and the time steps can be larger and thus fewer — this characteristic is often characterized in the literature as "coarse-grained parallelism."

This method follows an approach that combines the fully implicit Crank-Nicolson time-stepping method with a massive degree of parallelism in computation. This approach enables the application of fully implicit techniques; in comparison with explicit techniques, implicit techniques exhibit superior numerical properties (princi-



Computations for all *M* Time Steps in a numerical simulation of a spatially complex, time-dependent electromagnetic field are performed in parallel.

pally, unconditional stability) while also providing optimal efficiency for parallel computation. The time-parallel algorithm in this method imposes relatively simple requirements for communication and synchronization among different processors; this characteristic in combination with coarse-grained parallelism, makes for highly efficient implementation on emerging massively parallel multiple-instruction, multiple-data computers.

The basic equation of the method is obtained by applying the Crank-Nicolson method to the second-order inhomogeneous linear recursion (SOILR) equation of the finite-difference formulation of the Maxwell's equations. The resulting form of the basic equation is

$$(I-\alpha\mathbf{M})\psi^{(m+1)} = 2I\psi^{(m)} - (I-\alpha\mathbf{M})\psi^{(m-1)} + f^{(m+1)} \text{ for } 1 < m < M-1,$$

where I is the identity matrix, α is a constant, $\mathbf{M}$ is an $N \times N$ matrix that arises from the spatial discretization of the Laplacian operator in Maxwell's equations, $\psi^{(m)}$ denotes the solution (a vector that represents the electromagnetic-field quantity of interest) at the mth time step, and $f^{(m)}$ denotes the time- and space-discretized source term for initial and boundary conditions at the mth time step. The eigenvalue/eigenvector decomposition of $\mathbf{M}$ is given by $\mathbf{M} = \Theta\Lambda\Theta^{-1}$, where Θ is the set of eigenvectors and Λ is a diagonal matrix that represents the set of eigenvalues of $\mathbf{M}$.

Let there be a diagonal matrix

$$S = (I-\alpha\Lambda)^{-1}.$$

Let

$$\tilde{\psi}^{(m)} = \Theta^{-1}\psi^{(m)} \text{ and } \tilde{f}^{(m)} = S\Theta^{-1} f^{(m)}.$$

Then it can be shown that the basic equation can be put in the form

$$\tilde{\psi}^{(m+1)} = 2S\tilde{\psi}^{(m)} - \tilde{\psi}^{(m-1)} + \tilde{f}^{(m+1)}.$$

Unlike the basic SOILR equation as formulated in the preceding paragraph, this SOILR equation is diagonalized and can therefore be solved efficiently by use of either of two parallel-computation algorithms called the Recursive Doubling Algorithm (RDA) or the Cyclic Reduction Algorithm (CRA). For two- and three-dimensional problems, this SOILR equation can be solved in $O(N^2 \log M)$ and $O(N^3 \log M)$, respectively, on M processors, where $O(x)$ denotes an amount of computing time or a number of arithmetic operations proportional to a number of the order of x.

The figure illustrates the time-parallel algorithm, which is divided into four steps. Step 1 involves determination of the eigenvalue/eigenvector decomposition of $\mathbf{M}$ and the computation of S. In step 2, the source vectors $f^{(m)}$ are computed and multiplied by $S\Theta^{-1}$ to obtain $\tilde{f}^{(m)}$. The parallel computation to solve the diagonalized form of the basic SOILR equation is performed in step 3, yielding the vectors $\tilde{\psi}^{(m)}$. The desired solution vectors are computed in step 4 by matrix·vector multiplication; namely,

$$\psi^{(m)} = \Theta\tilde{\psi}^{(m)}.$$

This work was done by Amir Fijany, Michael A. Jensen, Yahya Rahmat-Samii, and Jacob Barhen of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*
NPO-19453

Physical Model of Immune-Inspired Computing

This model simulates several basic cellular and global functions of immune systems.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mathematical model that represents several physical and mental behaviors has been developed to enable the phenomenological description of basic functions of immune systems. This development is part of a continuing effort to improve the autonomy of robots and spacecraft by use of computational methods that exploit paradigms of human immune systems. The model can serve as a formalism for building artificial immune systems for computing and for other forms of information processing.

The discipline of artificial immune systems is a rapidly growing field of information processing based upon immune-inspired paradigms of nonlinear dynamics. The interest in immune-systems paradigms stems from the observation that an immune system serves as an excellent model of adaptive processes that occur at the local (cellular) and of useful behavior emerging at the global level.

Although artificial immune systems have many features in common with artificial neural networks, there are some differences that arise from the fact that immune systems perform many different functions simultaneously and, in comparison with neural networks, they are more complex and more diverse. In contradistinction to a neural network, an immune system, from the perspective of nonlinear dynamics, can be considered as a multibody system (the bodies being cells) in which the bodies are interconnected via flows of information. Inasmuch as these flows and the responses to them may be distorted, delayed, or incomplete, the motion of each cell becomes stochastic and can be simulated as a controlled random walk.

One of the main challenges in modeling living systems is to distinguish random walks of physical origin (for instance, Brownian motions) from those of biological origin. Following a line of reasoning from prior research, it was assumed, in the development of the present model, that a biological random walk must be nonlinear. The model is intended, more specifically, to simulate the main immune-system functions based on the dynamics of body cells interacting with invader cells. In contradistinction to prior stochastic models, the present model incorporates the concept of reflection; that is, the human ability to observe one's own thoughts. This concept renders the model more adaptable to the world of biological and social evolutionary processes.

The model consists of (1) a generator of stochastic processes that represents motor dynamics in the form of nonlinear random walks and (2) a simulator of the nonlinear version of the Fokker-Planck equation, representing the mental dynamics. Thus, the model is one of coupled mental/motor dynamics incorporating the concept of self-image. It has been demonstrated

that the model can simulate such basic functions of immune systems (and of cells within immune systems) as self-identification, self/nonself discrimination, self-repair, formation of acquired immunity, self-organization, predator/prey pursuit, and reproduction.

This work was done by Michail Zak of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*

NPO-21039

Mathematical Model of a Quantum Decision Maker

Autonomy would be achieved by use of feedback from mental to motor dynamics.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mathematical model of a quantum analog-computing device that would simulate the human decision-making process has been developed. Like the immune-inspired-computing model described in the preceding article, this model is intended to contribute to improvement in the autonomy of robots and spacecraft.

The device would include quantum recurrent networks that would represent motor dynamics, plus classical neural networks that would represent the evolution of probabilities of processes that, in turn, would represent mental dynamics. The decision-making process would be made autonomous by use of feedback from mental to motor dynamics. In the model, this feedback changes a stochastic matrix based upon distributions of the probabilities. The resulting coupled motor and mental dynamics are described by nonlinear Markov chains that can decrease entropy without recourse to an external source of information.

In terms of mental phenomena, the feedback would play the role of "common sense" in the form of invariants or patterns of behavior that can be abstracted from prior knowledge and experience and can be applied to whole classes of situations similar to those of immediate interest. Like "common sense," this feedback would be used in the quantum decision maker to replace unavailable external information by information from an internal knowledge base. The human ability to do this is recognized and widely exploited in psychology and has been known, since the time of ancient philosophers, to follow from the fact that a human possesses a self-image and interacts with it.

In the model, a quantum recurrent network is regarded as a quantum system represented by an equation that describes the relationships among (1) the inputs to the network at time t, (2) the outputs of the network at a later time $t + \tau$, (3) a set of unitary operators that are defined by the Hamiltonian operator of the quantum system and express the temporal evolution of the quantum system, and (4) a measurement operator that projects the evolved quantum state into one of the eigenvectors of the system. The effect of

the measurement operator can be characterized as similar to that of a sigmoid function in a classical neural networks. Because of the stochastic nature of quantum measurements, the outputs at time $t + \tau$ are random; as such, these outputs form a Markovian stochastic process.

The internal knowledge base is stored in a mental submodel in the form of probability distributions. Formally, the knowledge base is represented by the synaptic weights of neural networks, and the knowledge is divided into two parts. The first part includes knowledge that pertains to personal experience, habits, and such inclinations as averseness or proneness to risk. The second part depends upon an objective formulated in terms of probability invariants. Dependence upon the objective can include learning modeled by real-time adjustment of synaptic weights, adapted from theory of neural networks. As soon as the synaptic weights are determined, the common-sense-simulator portion of the model follows an optimal strategy, regardless of unexpected changes in the external world.

This work was done by Michail Zak of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*
NPO-21038

IIR Filters for Postprocessing Noisy Test Data

John F. Kennedy Space Center, Florida

A little-known parametric form of an infinite impulse response (IIR) filter has been found to be useful in digital postprocessing of noisy test signals. The filter equation is:

$$y(n) = \alpha[x(n) + x(n-1)] + \gamma y(n-1),$$

where α and γ are parameters and $x(n)$ and $y(n)$ are the input and output, respectively, during the nth sampling period. The parameters are given by

$$\gamma = \cos\theta_c/(1 + \sin\theta_c) \text{ and } \alpha = (1-\gamma)/2,$$

where $\theta \equiv 2\pi f/f_s$; $\theta_c \equiv 2\pi f_c/f_s$; and f, f_s, and f_c are frequencies. This parametric form simplifies postprocessing and analysis of the data by making it easy to tune the filter response through selection of the low-pass cutoff frequency, f_c. Whereas parameters in other forms of IIR filters are restricted to discrete values, the parameters in this form can be selected from nearly continuous ranges. The filter response in this form is inherently stable over the entire digital frequency range from zero to the Nyquist frequency (half of the sampling frequency, f_s). Although the stability is robust, it deteriorates with a decrease in the number of bits used to represent coefficients and filter states.

This work was done by Jan A. Zysko and Christopher M. Amis of **Kennedy Space Center** *and John E. Lane of Dynacs, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*
KSC-12218

Books & Reports

Tests of Finger Seals

A report discusses tests of finger seals, which were described in "Pressure-Balanced, Low-Hysteresis Finger Seal" (LEW-16840), which appears on page 52 in this issue. Like a labyrinth or brush seal, a finger seal is used (typically in a gas turbine) to minimize a leakage flow along a rotating shaft. The report describes baseline (subject to considerable hysteresis) and pressure-balanced (low-hysteresis) brush seals and presents results of hysteresis, performance, and endurance tests of the seals in a seal rig at Glenn Research Center. The report concludes that a finger-seal design is ready for engine testing.

This work was done by Margaret P. Proctor and Bruce M. Steinetz of **Glenn Research Center**, *Gul K. Arora of AlliedSignal Engines, and Irebert R. Delgado of the U. S. Army Research Laboratory. To obtain a copy of the report, "Pressure-Balanced, Low-Hysteresis Finger Seal Test Results" access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16973.

Low-Power, Zero-Vibration Sorption Coolers

A report discusses three designs of proposed low-power, zero-vibration coolers for infrared instruments planned to be flown aboard spacecraft to perform astrophysical observations far from Earth. The designs take advantage of the radiative precooling available in the projected deep-space operational environments: such precooling makes it possible to reach radiator temperatures as low as tens of kelvins. The working fluids would be helium and hydrogen, and vibration would be eliminated by the choice of thermally cycled gas-sorption (hydrogen/metal hydride and helium/charcoal) units instead of mechanical compressors.

This work was done by Lawrence Wade and Christian Lindensmith of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Low-Power, Zero-Vibration 5K Sorption Coolers for Astrophysics Instruments," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
NPO-30369

Inhibited Carrier Transfer in Ensembles of Quantum Dots

A report presents an experimental study of time-resolved, temperature-dependent photoluminescence in $In_xGa_{1-x}As/GaAs$ specimens containing $In_{0.6}Ga_{0.4}As$ quantum dots (QDs) distributed at several different areal densities on a GaAs surface and capped with GaAs. The specimens were fabricated by metal-organic vapor deposition of $In_xGa_{1-x}As$ on slightly misoriented, semi-insulating GaAs(100) substrates. At high areal densities, the intensities of photoluminescence from the QDs were found to exhibit Arrhenius temperature dependence, attributed to thermal emission of charge carriers and recapture of the charge carriers into neighboring QDs. At low densities, it was found that the temperature dependence is more complex, the thermal transfer of charge carriers between neighboring QDs plays no significant role in the temperature dependence, and the efficiency of transfer of charge carriers into isolated QDs is limited by the rate of carrier transport in $In_xGa_{1-x}As$ wetting layers.

This work was done by Rosa Leon and Charlene Lobo of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Inhibited carrier transfer in ensembles of isolated quantum dots," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
NPO-21029

Study of Amplification in Optocoupler-Equivalent Circuits

A report presents a theoretical and experimental study of amplification in electronic circuits that include combinations of discrete light sources (e.g., light-emitting diodes) and photodetectors (e.g., reverse-biased photodiodes), which combinations perform essentially

the same functions as do the commercially available, packaged light-source/photodetector combinations denoted, variously, as optocouplers, optoisolators, and the like. The report calls these circuits photo-electric amplifiers (which should not be confused with photoelectric amplifiers). The report discusses the basic considerations of current, voltage, impedance, transformer coupling, source/detector optical coupling, bias and load resistances, and other phenomena that affect current, voltage, and power gains. Limitations and design concerns for making photo-electric amplifiers function as linear amplifiers are also discussed. Tests of amplifiers and oscillators based on photo-electric amplifiers are described. An addendum to the report discusses the use of photo-electric amplifiers to make digital-logic elements for data-processing circuits ranging from process controllers to computers. Finally, it is reported that experimental AND, OR, and NOT gates were constructed and tested to demonstrate this concept and were found to function as predicted.

This work was done by John M. Franke of **Langley Research Center.** *To obtain a copy of the report, "Photo-Electric Amplifier," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*
LAR-15460

Area Production in Supercritical, Transitional Mixing Layers

This paper presents a study of area production in mixing layers undergoing transition to turbulence. These layers evolve from the mixing of two initially segregated counterflowing streams under supercritical conditions. The study may contribute to development of means to control area production in order to increase disintegration of fluids and enhance combustion in diesel, gas turbine, and liquid rocket engines. As used here, "area production" signifies the fractional rate of change of surface area oriented perpendicular to the mass-fraction gradient in a mixing layer. In the study, a database of transitional states obtained from direct numerical simulations of temporal three-dimensional supercritical mixing layers for heptane/nitrogen and oxygen/hydrogen systems was analyzed. A few of the many conclusions drawn from the analysis are that area production is determined more by strain than by compressibility; area is produced by strain and convective effects; area is destroyed by species mass flux, rotational effects, and pressure gradients; area can be either produced or destroyed by pressure gradients; and effects of viscosity on area production are negligible. Effects of departure from perfect-gas and ideal-mixture behavior were found to be important. Smaller-wavelength initial perturbations were found to lead to greater area production: this observation could be a guide to initial development of control of area production.

This work was done by Josette Bellan and Nora Okong'o of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the paper, "Area Production in Supercritical, Transitional Mixing Layers for Reactive Flow Applications," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
NPO-30425

Nanolaminate Mirrors With Integral Figure-Control Actuators

A report discusses the development of thin-shell curved mirrors comprised of metallic multilayer nanolaminate substrates that contain integral in-plane actuators for controlling surface figure with micron-level precision. These mirrors, intended for incorporation into scientific imaging systems, would have areal mass densities of <2 kg/m^2. The development involves the combination of emerging disciplines of nanolayer composite materials, electroactive materials, and mathematical modeling for the understanding and controlling elastic deformations of thin-shell structures. Nanolaminates constitute a relatively new class of materials that can approach theoretical limits of stiffness and strength. The report details the mathematical-modeling aspect of the development with a brief discussion of experiments on nanolaminate specimens.

This work was done by Gregory Hickey, Shyh-Shiuh Lih, and Troy Barbee of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Deformable Thin Shell Nano-Laminate Mirror," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Materials category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-30221, volume and number of this NASA Tech Briefs *issue, and the page number.*

Paraffin-Actuated Heat Switch for Mars Surface Applications

Missions to the surface of Mars pose unique thermal-control challenges to rover and lander systems. With diurnal temperature changes greater than 100 °C, the presence of a Mars atmosphere, and limited power for night-time heating, the thermal-control engineer is faced with a fundamental problem: how to successfully keep components above their survival or operating temperatures at night while managing higher environmental temperatures and dissipation rates during the day. A report describes such a paraffin-actuated heat switch as part of the thermal-control system for a robotic exploratory vehicle on Mars. Over a predetermined temperature range, the switch heat conductance varies by nearly two orders of magnitude to regulate temperatures. The actuation of the heat switch is entirely mechanical and autonomous, relying on the temperature based expansion and contraction of paraffin contained in a seal boot.

This work was done by Keith S. Novak, Gajanana Birur, Eric Sunada, Michael Pauken, Charles Phillips, and Donald Sevilla of Caltech and Kurt Lankford of Starsys Research Corporation for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Paraffin Actuated Heat Switch for Mars Surface Applications," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

NPO-30351

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Microscan, Renton, WA, offers the Quadrus EZ™ bar code scanner that allows manufacturers to use 2D symbols to track components and boards. The system combines a vision system with a laser bar code scanner. A field-of-view locator lets the user positively align the reader to the symbol without the use of video monitors or a PC. Once the symbol is aligned, the system automatically calibrates on the symbol. It decodes both linear and 2D codes, at 60 codes per second. **For Free Info Circle No. 713 or Enter No. 713 at www.nasatech.com/rs**

Computer Workstations

IBM, Armonk, NY, has introduced a line of UNIX®, Linux®, and Windows-based IntelliStation® workstations. Supporting 2D and 3D graphics accelerators, the workstations are available with the company's T210 flat panel monitor. The IntelliStation POWER 265 UNIX workstation contains one or two 450-MHz, 64-bit POWER3 microprocessors. The Pro Series workstations feature Intel Pentium® 4 and Xeon processors at 2.2 GHz. **For Free Info Circle No. 701 or Enter No. 701 at www.nasatech.com/rs**

FEA Solver

ALGOR, Pittsburgh, PA, offers new solver technology for linear static stress and steady-state heat transfer analyses that use sparse solver technology to provide faster processing times. The software is available for PC workstations running on Windows NT, Me, 98, 2000, or XP. Customers with current software upgrade subscriptions can receive sparse solver technology at no charge by requesting the latest updates for the linear static stress and steady-state heat transfer products. **For Free Info Circle No. 702 or Enter No. 702 at www.nasatech.com/rs**

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The HH501DK four-channel Type-K thermometer from OMEGA Engineering, Stamford, CT, accepts K type thermocouple probes and covers ranges from -50 to 1300°C. It features four standard miniature connector inputs, a 3-1/2 digital display with backlighting, and a read HOLD and MAX function. The thermometer provides differential temperature readings of T1-T2, T1-T3, and T1-T4. **For Free Info Circle No. 703 or Enter No. 703 at www.nasatech.com/rs**

New LITERATURE

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A 166-page catalog from Loctite Corp., Rocky Hill, CT, details adhesive, sealant, coating, cleaner, and lubricant products, as well as dispensing and curing equipment. The book is organized into application categories including assembly products for industrial applications, electronic products for microelectronics assembly, and medical products for medial device manufacturing. **For Free Info Circle No. 705 or Enter No. 705 at www.nasatech.com/rs**

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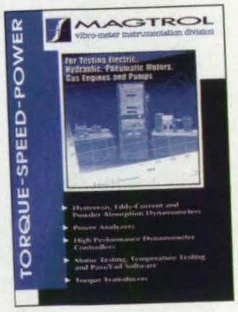

Magtrol, Buffalo, NY, offers a brochure on torque-speed power products for testing electric, hydraulic, pneumatic motors, gas engines, and pumps. The brochure describes in-line torque transducers and display units, hysteresis, eddy-current and power brake dynamometers, high speed dynamometer controllers, and power analyzers and software. **For Free Info Circle No. 707 or Enter No. 707 at www.nasatech.com/rs**

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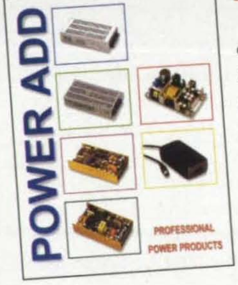

Power Add USA, Lowell, MA, offers a 32-page catalog of desktop switching power supplies from 25 to 50 watts, open frame switching power supplies from 30 to 70 watts, and U-channel switching power supplies ranging from 60 to 350 watts with single, dual, tripe, and quad outputs. Also included are the LB and LBP series switching power supplies ranging from 25 to 150 watts. **For Free Info Circle No. 708 or Enter No. 708 at www.nasatech.com/rs**

Oscillators

MF Electronics, New Rochelle, NY, offers a six-page product guide describing clock oscillators, VCXOs, TCXOs, and crystals. The guide highlights specifications for time and frequency reference source for wireless and datacom applications. **For Free Info Circle No. 709 or Enter No. 709 at www.nasatech.com/rs**

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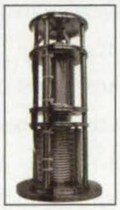

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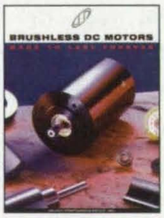

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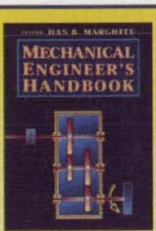

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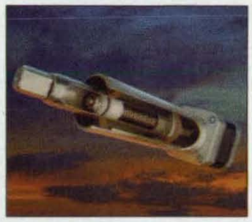

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